McDERMOTT. W. • GOLD AMALGAMATION

Publication No. 29. Code Word: ASPIRARON.—2nd Edition.

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# LOSSES

—IN—

# GOLD AMALGAMATION

WITH NOTES ON THE

## CONCENTRATION OF GOLD AND SILVER ORES.

—BY—

WALTER McDERMOTT AND P. W. DUFFIELD.

Special Edition

FOR COMPLIMENTARY DISTRIBUTION



HAMBLIN PRINTING CO. 418-420 DEARBORN ST, CHICAGO.

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# GOLD AMALGAMATION:

WITH NOTES ON THE CONCENTRATION OF GOLD AND SILVER ORES.

(WITH SIX PLATES.)

BY


WALTER McDERMOTT AND P. W. DUFFIELD.



FRASER & CHALMERS,

CHICAGO, ILL.

1890

We offer to our customers, by permission of the Authors, a pamphlet on the subject of "LOSSES IN GOLD AMALGAMATION AND CONCENTRATION OF GOLD AND SILVER ORES," which we believe may be found suggestive in overcoming certain difficulties in working exceptional Ores by modifications in existing and well established machinery, and involving no new processes or experimental apparatus.



# CONTENTS.

# PREFACE.

The purpose of the following notes is not to give a detailed description of milling processes and machinery, but to offer a little useful knowledge to directors of English gold mining companies on some of the simple principles that are too often ignorantly, or designedly, ignored or surrounded with mystery by inexperienced mine managers; also to give to millmen a few suggestions, founded on a tolerably wide experience, in the commercial handling of many kinds of ores. Some directors of mining companies are naturally inclined to listen to the specious promises of inventors of novel processes and new machinery, forgetting their own personal disadvantage in any argument on such matters, and assuming a confidence in the logic of their own conclusions, while they ignore the fruitful experience of thousands of practical men who are engaged in the mining business. The repeated failures of directors in sending out new machinery to their mines, ought by this time to be sufficient warning against increasing risks that are at once natural and unavoidable, and to deter them from plunging their shareholders into experiments which, in ninety-nine cases out of a hundred, result in nothing but excessive and needless expense.

It is certain that new machinery and new processes are, and will be, given attention by mining men in proportion to their probable merits; but the proper place for experiments is in a mill already as successful as known processes can make it. In a new enterprise, even when the expense of an experiment is undertaken by the inventor, the loss to the mine owner in case of failure must be very great, both in time and general running expenses. Directors should not believe that a willingness to risk cash in proving an invention is necessarily any proof of value of the same; it is only a measure of the faith of the inventor, which is hardly a safe standard by which to risk shareholders' money.

The variety of modifications in approved processes to which reference will be made, ought at least to suggest the desirability of exhausting the known before drawing on the unknown and purely speculative. It should also be borne in mind, that what might appear at first sight to be new processes, and even new machinery, are in fact, often nothing but old contrivances and plausible theories long ago exploded among practical men.

# LOSSES

IN

# GOLD AMALGAMATION,

## PART I.

BEFORE attempting to lessen a stated loss in gold amalgamation, it is necessary to establish exactly (1) the amount, and (2) the form in which it occurs. Although copper-plate amalgamation in not a perfect system, it is much better in results than many inventors of new processes believe. It is very common, as an introduction of new machines or processes, to state, on the strength of some ancient Government report, that the loss of gold in milling is from 30 to 50 per cent. This is simple nonsense as a basis of calculation for improvements. In the first place, Government reports on mining results are not necessarily reliable, except perhaps as to product in some places; and the miners always know their business well enough to get their own ideas incorporated in the reports of Government officials. It can generally be assumed that an owner of a mine is willing to have his tailings assay as high as possible in reports; it makes his ore so much the richer, and leaves a good ground of argument for increased value of property if the purchaser will only put in more perfect machinery. However, the question of Government reports is not worth considering, because even they at present do not show anything like the losses which are seen in the reports of fifteen years ago, still quoted by inventors. For example, a simple reference to the California State Mineralogist's report will show that tailings assays in modern mills average now from ¼ to 1½ dwt. per ton.

The following table gives results at a few typical gold mills, and will be interesting as an offset to the frequent outcries about universal large losses in gold milling:—

| Name of Mine or Company. | Average of Ore. | Assay of Tailings. | No. of Stamps. |
|---|---|---|---|
| | dwts. | dwts. | |
| Homestake Company.................... | 4 to 4½ | ⅓ to ¾ | 120 |
| Alaska Mining Company................. | 5 | ½ to 1 | 240 |
| El Callao.... .......................... | 25 | 3½ | 60 |
| Yuba.................................. | 8½ | ¼ | 15 |
| Plumas Eureka............... .......... | 7½ | 1 | 60 |

In California, on a considerable variety of gold ores, the percentage of gold saved averages 80 to 85 per cent., and most careful daily tests in some of the best gold mills using concentrators show 85 to 90 per cent.

It is perfectly obvious, if mill tailings are averaging in value 50 to 75 cents per ton by the cheapest and simplest of all processes, that the chances of improvement, except in mere matters of economy, of handling the ore, and wear of machinery, are very slight for the inventor; therefore the very first essential of improvement is to find out exactly how much room there is for it. In this connection some of the reports of mine managers and directors are very amusing. The assay of the tailings is often assumed to be the difference between what the ore is supposed to contain and what it actually yields. The value of the ore is itself arrived at by various and extraordinary methods; such as reference to the report of the expert on which the mine was purchased; the returns of occasional assays by mine foremen of good ore; the results of neighboring mines on the same vein, etc. Or again, actual assays of tailings are taken, but from such samples that they are equally worthless as the estimates of ore value. It is very common for a sample of tailings to be dug out of the pit where it has been concentrating by the flow of pulp for weeks; or from the bed of a river below the mill, in which latter case the greater the distance down the stream the more damning are the results presumed to be against the mill. In still other cases, where regular proper samples are taken as tailings flow, and those samples give low assays, they are doubted, on the ingenious supposition that the gold has floated off with the water, or evaporated in the steam if boiled down to dryness; every theory, in fact, except the fact alone useful to know, that the ore working on a large scale is of lower average value than was supposed from assays in the mine. It often happens that in starting work on a mine with a small stamp mill, the yield per ton of ore is for a time satisfactory and up to calculations, because the mill can be supplied with ore from the best portions of the vein; but on adding a larger mill the conditions are all changed. The mine must then be worked regularly and systematically, and the large consumption of rock by the mill makes it impossible to pick out the ground as before; consequently the yield per ton runs down at once. This simple explanation of lower yield is often kept out of sight by specious assertions as to large loss in tailings. The late experience in some African mills illustrates this fact by figures that can be understood by the most inexperienced, and these figures—from two well-known mines, the Robinson and Jumpers—are as follows:—

The Robinson mine produced in the neighborhood of 4000 oz. of gold monthly with 10 stamps. When 80 more stamps were added the yield of gold was 8000 oz., from more than four times the quantity of ore formerly producing 4000 oz. In other words, the grade of the ore dropped 50 per cent. when the crushing capacity was increased four-fold.

The Jumpers mine in its first workings, on 28,000 tons of ore, gave an average yield of 20 dwts. gold per ton. In six months' work with 30 stamps, the yield was 18¼ dwts. The result of the first month's run with 70 stamps give 11¾ dwts. per ton; and the second month's run with 70 stamps, 10¾ dwts. In these two cases, the management being good, no question of increased loss in tailings has arisen; but in many smaller mines such explanations would be jumped at by directors, and inventors of new processes would be listened to respectfully.

As to the loss that does occur in gold amalgamation, it is very easy to determine both the quantity and form of loss, equally necessary to be known before proceeding to improvements. Small samples are taken from the waste outflow of the mill—or separately of the different batteries—at regular intervals, until a bucketful is collected, which is allowed to settle for several hours, the clear water poured off the top, and the residue evaporated to dryness; then well mixed, sampled, and assayed. Even in



the dipping out of each small sample, an error may be made if the vessel be allowed to overflow, so producing a concentration of heavy sand and mineral. Samples properly taken in this way daily, and averaged up, will establish the assay value per ton of tailings; and the samples have then to be examined to determine what state the gold is in. An automatic sampler for mill tailings is of great utility, and more reliable than the irregular sampling by some employed, as is usual. The loss will be in one or more of the following forms:—

(1) Loss of free gold, quicksilver, or amalgam, all due to careless or inexperienced amalgamation.

(2) Free gold and gold-bearing sulphurets, attached to or imbedded in particles of rock.

(3) Gold contained in base metal sulphides, broadly termed "sulphurets."

(4) Gold in the fine slimes.

(5) A condition of gold in which it is not susceptible of copper-plate amalgamation.

The inventors of new processes usually ignore these distinctions. It may happen that experiments show a good result on a certain ore because the loss of gold occurs in a certain way, and the inventor of limited experience hastily assumes from his results that the process is equally applicable to all gold ores, irrespective of the differences in their characters and conditions of the gold loss. The first test is to determine under which of the above heads the serious loss occurs, for some loss may be found in each class; and a process which may be effective on fine gold, for instance, may be utterly useless on sulphurets, and *vice versa*.

A fair average of the daily tailings samples is examined as follows:—

(A) It is panned down very carefully, to determine if free gold, or amalgam, or quicksilver is to be seen. If any of these be found, no further tests on tailings samples are necessary until the man in charge of the amalgamation is replaced, or instructed in his business. In making this simple test it must be borne in mind that evaporating the tailings at a high heat may drive off any fine quicksilver. It is to be noted that the use of quicksilver wells before the copper plates is a cover for careless or inexperienced work; with plates immediately below the screens a perfect index is afforded of work inside the battery, and of the proper proportioning of quicksilver feed or the contrary; while the quicksilver well hides the fact of an excessive feed of quicksilver or the reverse, for some time. The gold that is caught in a quicksilver well will never get past the plates, if these be in good condition.

(B) A quantity of the average sample is sized on screens, say 60-mesh and 100-mesh brass wire cloth, and each of the three sizes so obtained weighed to determine their relative proportions, and assayed separately. If the portion remaining on 60-mesh assays quite appreciably above the finer sizes, the loss by imbedded gold can be diminished only by finer crushing, either in the battery, or outside by a subsequent grinding, to be treated of later on. The coarse portion on the 60-mesh should be ground finer in a mortar, and panned, to see if the loss is in free gold or sulphurets, as this would have a bearing on what batteries and coppers alone would do by finer crushing. Should the assays show approximately equal value in the coarse as in the finest particles, it is clear that to use a finer screen in the battery would simply diminish capacity, without materially increasing the percentage saved. If the slimes below 100-mesh assay higher than the other sizes, a coarser screen in the battery will probably give better commercial results, by increased capacity without increase of loss.

(C) A weighed portion of the average tailings sample is next vanned or panned down, to determine if any sulphurets exist, and if so the percentage of the same. The sulphurets washed out are assayed, to establish their value with reference to

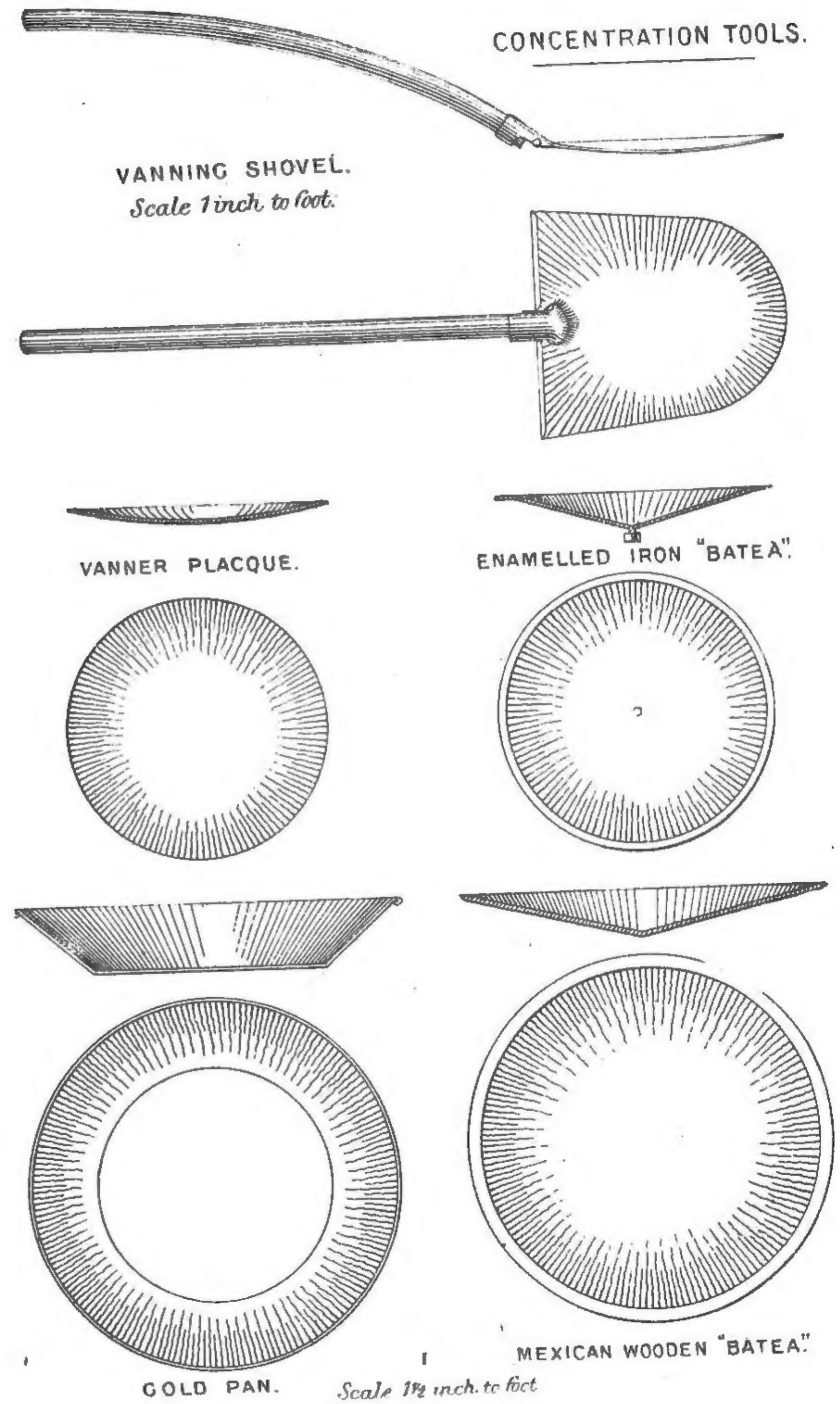
commercial treatment after concentration. The weight and assay value of sulphurets, calculated on the weight of sample washed, will give the value per ton of original tailings saved in the form of sulphurets. In this test, of course, it is assumed that test (A) has been previously applied, because imperfect amalgamation would vitiate the sulphuret concentration test by introducing amalgam into the concentrates. This concentration test requires more skill to make than the preceding, because the fine sulphurets are by no means easy to save close by a hand test. The tools used for this work are shown on Plate 474. If an ordinary gold-pan be used to wash with, the process must be repeated at least three or four times, washing from one pan to another and back again, and collecting each time the sulphurets; for the gold-pan is a very imperfect appliance for saving fine mineral, and a Frue vanner in practice will give both cleaner concentrates and poorer tailings than a hand test will show. The Cornish vanning shovel is a far better tool than a gold-pan for sulphurets, but not so good for free gold or amalgam. The angles of the sides of a gold-pan collect the free gold, but cause a disturbing ripple in the water when washing sulphurets, which floats them off. As a curious instance of ignorance of this fact, it is sometimes claimed by inventors of concentrators for sulphurets, that they have imitated the action of a pan; and it only needs the washing of tailings from a pan to show how poor a tool it is for sulphurets, even when it has a head over it, which a machine cannot replace. The vanning placque is a circular flat curved dish of sheet iron, enameled white all over, to prevent rust and to show up better the color of the sulphurets. In shape it is practically a vanning shovel without a handle, but, like the latter, it requires a special skill in its use, obtained only by practice. Its advantages are, white surface, freedom from rust, and convenience of carriage, as it will go in an ordinary valise. The Mexican batea is also a very good tool for hand tests, for both free gold and sulphurets, and requires much less skill for collecting the mineral than a shovel or a placque. This tool can now be obtained of enameled iron, which, while perhaps not as perfect for catching some flaky gold as the rougher wood surface, is better than the latter for concentrating sulphurets, and equally good for fine gold. A steady circular shake without revolving, alternated with a reciprocating circular motion, settles all heavy mineral into the central depression, and an immediate rapid wash of the water towards one side carries off the sand in a fan-shape to the edge, leaving the gold or sulphurets showing at the apex of the cone of material. For hand tests on a weighed quantity, it is very convenient to drill a small smooth hole, say ⅛ of an inch, in the very center of the batea, and put a small cork or wooden plug in from below, flush with the inside surface, to close while settling and spreading; then remove the plug, holding the batea over an evaporating dish, and wash down through the hole by a fine jet from a wash bottle, all the clean mineral showing. The plug is then again put in, a little water put on the batea, and the material again well shaken, settled, and spread, and the mineral washed out below; the process being repeated until no more mineral can be separated. A flat-shaped evaporating dish is sometimes used for these hand tests, but it is difficult to get one of good form, as any slight shortening of radius of the curve near the edge is fatal to good work, by necessitating a steep inclination to wash off the sand.

(D) The total losses from fine gold in the slimes, are practically covered already by the sizing test (B), which will give the proportion in the slimes below 100-mesh, but in this would be included a loss due to sulphurets, which can be avoided in large measure by concentration. A very careful concentration test on the slimes alone will then establish the approximate loss due to fine gold. The loss of fine, or "float" gold as it is often called, when its limit is established by the above tests, will usually be found, on calculation of percentage of weight involved, to be less serious than imagined on most gold ores.



**PLATE 474. CODE WORD: ROGREFFEUR.**

**Fraser & Chalmers, Chicago, Ill.**



(E) To determine whether the fine gold in the slimes is amalgamable by a more effective system than copper-plate process, is only worth while in cases where above tests show that there is a profitable commercial advantage in adopting a more complicated process; for it is ridiculous to lose sight of the question of profit in the search after a perfect result. Where the loss is very high in the slimes, it will doubtless be found also high in the coarser sizes of tailings; and, as a consequence, it becomes really a question of another system of treatment for the original ore, not solely of the slimes; it can therefore be treated under the head of "gold in a condition not susceptible of amalgamation on copper." The best test of the highest amalgamation obtainable is by use of an amalgamation pan, either large or small. Small laboratory pans are made, which can be run either by hand or from any running shaft, and will take a charge of 3 to 5 lbs. of ore. These small pans, if properly constructed and run, will give results closely approximating mill work by pan amalgamation.



# THE TREATMENT OF GOLD ORES.

The above examinations and tests, if carefully carried out, will determine the actual average loss on the mill tailings, and the form in which it occurs, as a necessary preliminary step to adopting improvements which will now be considered. The possible improvements will divide themselves, according to previous divisions of the loss, into:—

(1) The employment of greater skill in copper-plate amalgamation.

(2) The freeing of gold locked up in rock particles.

(3) The concentration and separate treatment of the sulphurets.

(4) and (5) The adoption of a more effective system of treatment.

No arbitrary division can be made of these, as more than one of the remedies may be necessary in any given case, but it is simpler to treat them separately for convenience of reference.

### (1) Skilful Amalgamation.

It is not possible to supply the lack of skill and experience by instructions, and the owners of mills should take the only safe course in this part of the business, by employing a good millman who has a record of successful work elsewhere. The owner of a mine, or the directors of a company, may be impressed with the bearing and talk of an applicant for the position, but the frequent and lamentable failures resulting from this method of choosing a millman are proofs of its inadequacy. Testimonials as to character and experience need just as much examination as the applicant himself. Past successful record in modern mills is the only testimonial of real value. The salary to be paid a good man should be the last consideration; a cheap man is often a ruinous investment, for the final success of a mining enterprise rests on the successful treatment of the ore.

The form of mortar, the method in which the battery is fed, height of the drop of stamp, the hardness of plates inside and outside respectively, the frequency of cleaning up, and many other small matters, all have important bearings on results; and experience and constant watchfulness are the only guides in such matters. Book instruction is of little value to experienced men, and no others should have any authority in a mill. When, however, anything beyond good amalgamation is involved, there are many experienced millmen used to this part of the business, but without experience in other branches, as their work has been in districts where such knowledge sufficed for the ores; and therefore what follows on the matter of special improvements can be justified, as drawn from a wider knowledge of difficulties met and overcome than some good gold amalgamators have.

As a possible means of slightly increasing the amount of gold amalgamated, a shaking copper-plate with riffle is to be recommended. The so-called "amalgam saver" attached to the feed distributor of the Frue vanner, is simply a short strip of electro silver-plated copper, which, being attached to the shaking frame of the ma-

chine, moves with it, and the pulp flowing over it has a chance of depositing some fine gold by the shaking motion effecting a contact of the particles with the surface. An ordinary fixed copper-plate requires from 1½ to 2 inches fall in the foot to keep it clear of sand when the plate is full width of the battery; but if a short quick shake be given the copper it will keep clear and do good work with an incline of ¼ to ½ inch to the foot. Electro-plated copper is better than plain copper for these auxiliary plates, which can be swung on a light wooden frame and driven by a crank shaft placed on one side with a throw of about 1 inch at right angles to direction of pulp flow, and making 180 to 200 revolutions per minute. At the top of the copper-plate, a strip of wood ½ inch thick should be nailed across the full width between sides of table, forming a riffle, behind which a light body of the coarser sand and sulphurets collects, and remains in lively motion by the shaking action, so forming the most effective contrivance for catching quicksilver or hard amalgam which has yet been devised. Should, by accident or neglect, the inside copper suddenly harden and chips of amalgam escape by the screen, small pellets and marbles of clean hard amalgam will be found behind this riffle, rolled up by the shaking motion, and increasing in size just as a snow ball will when rolled in snow. It will pay well, in some cases, to use a number of these shaking coppers, 4 feet wide and 4 feet long; dividing the pulp of the upper coppers thinly over them, to increase the chances of contact with the fine gold particles. The copper is better used in giving all the width possible, rather than length of plate; a sheet of copper 4 feet by 8 feet will save more gold if made into two shaking tables 4x4 for 5 stamps, than as one table 4x8 feet. This shaking table arrangement has much to commend it, and was used by the writers in Montana in 1878. It is now used in some mills in California with marked success. In the case of one mill, Mr. J. H. Hammond, M. E., reports a saving of $50 worth of amalgam per day, below the ordinary copper-plates. A sketch is given on Plate 476, of a convenient form of shaking copper with amalgam riffle, supported on four short rocking legs. The table can of course be hung on rods from above; but is then not quite so clear and convenient for cleaning up.

Blanket sluices are still used in many places, and their chief advantage lies in the fact that when set at the proper inclination for the ore and frequently washed, they will save fine amalgam; but used as they sometimes are for the concentration of sulphurets, they cannot be defended. Even as amalgam-savers the shaking coppers and riffles are much to be preferred, as giving an available product of amalgam, not a mass of sand and sulphurets containing some specks of amalgam. If sulphurets are worth saving, they are worth saving in a comparatively clean form; not necessarily by so perfect a machine as the Frue vanner, but at least by some simple form of concentrator free from the defects of the blanket sluice, which, if set to save fine minerals, becomes clogged up very quickly with coarse sand. In 1873 it was a very general practice in California to use blankets, and some form of pan or other amalgamator for working up the blanketings; but this process has practically gone out of existence in the United States, owing to the evident advantages of simple plate amalgamation, and close concentration of the sulphurets, if any occur in the ore.

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### (2) Finer Crushing.

The immediate suggestion of the discovery of free gold in the coarser rock particles, is to use a finer screen in the battery; but there are disadvantages to be also considered in this simple remedy. The finer screen will at once diminish the capacity of mill, i. e. increase cost per ton of milling, and probably decrease monthly yield of bullion—and may increase loss of gold in slimes, and also of fine sulphurets, where the ore contains base metals. There is in all cases a compromise point between ex-



PLATE 476. CODE WORD: ROGREGARIA.

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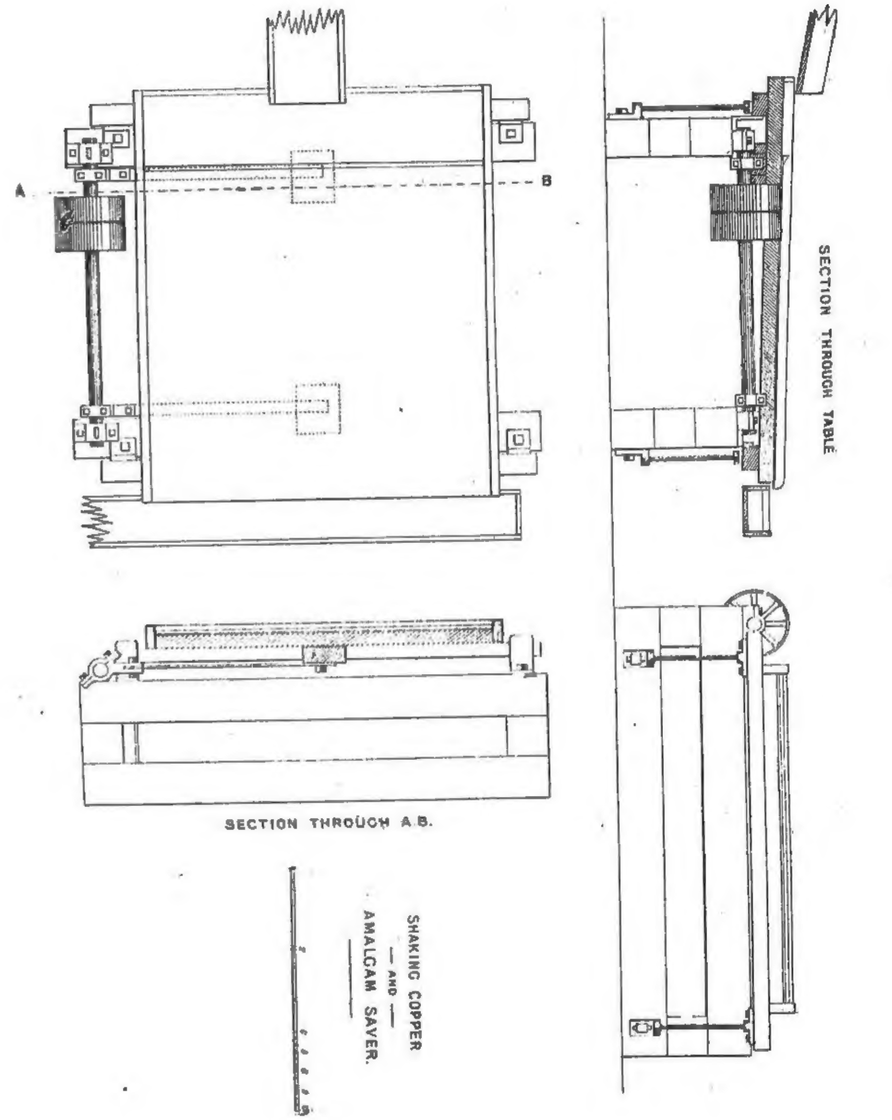


cessive loss and highest saving, wherein the best profit of milling will rest; this point depends on local conditions of cost of working, and value and nature of ore, so that only experiment can determine it.

### Regrinding Coarse Tailings.

There is, however, a method which promises in some cases to allow of large capacity and the maximum saving by copper-plate amalgamation. This consists in re-grinding the coarser part of the tailings and again amalgamating. The separation is effected either by shaking or revolving screens; or simpler still by hydraulic sizers. In this latter arrangement a small pointed box is employed, with an upward jet of water, which prevents any but the heaviest and coarsest pieces from discharging at the bottom opening. The tailings flow into and out of the box, and the regulation of the quantity of water flowing controls the size of the particles discharged at the bottom. Plans of this apparatus are shown on Plate 475, page 36. The coarse portion, discharged from the lower opening of the box, goes to re-grinding machines—such as Heberle mills, Huntington mills, arrastras, grinding-pans, etc.,—and then again over copper-plates, to extract the gold freed by the grinding of the rock particles. The introduction of the excess of water by the hydraulic sizer in the overflow portion, may cause some inconvenience should concentration be afterwards used, and in such cases large pointed settling-boxes can be used to again separate this excess of water, as illustrated in Plate 231, page 28, and described under the head of Concentration. Trouble under this head can be avoided where battery screens are not very coarse, by concentrating before the separation of coarse from fine is effected.

The advantages of this procedure, when possible, are apparent. A comparatively coarse screen can be used for the stamps, a large capacity be attained, unnecessary grinding of gold and sulphurets avoided, and yet a fair percentage of both free gold and sulphurets be extracted. There is practically no addition to the machinery, except the grinding-mill for a small quantity of material per day; the settling-boxes require no attention if built properly, and can be made by any carpenter on the ground. Having established the process, the battery screens can be tried coarser and coarser till the proper limit of economy is reached. In many cases millmen will make more profit by attempts to use coarser screens than finer. When the ore contains a large percentage of sulphurets, the advantage of the method described is added to by the decrease in proportion of slimes produced for subsequent concentration, and in such cases the concentration machinery is modified for treating the coarser mineral, as will be described later.

The use of the hydraulic sizer is very simple, and its various forms and regulations are described more in detail on page 35.

### (3) Concentration.

The close and automatic concentration of sulphurets is the most marked improvement of late years in treating gold ore. The copper-plate process itself has practically been unchanged for years, though great improvements have taken place in the constructive details of mills, so that increased capacity and greater economy of handling ore have resulted. But the close concentration of sulphurets, and subsequent treatment of the same after roasting, has, more than anything else, lessened the average loss of gold in milling; so that taking out a few exceptional ores, gold mill tailings nowadays need not be of any great commercial value, as shown in the table already given (page 5). The application of concentrating machinery is of course limited to ore in which the quantity and value of sulphurets will justify the separat-



ing of them and subsequent treatment; and a very large proportion of gold ores do contain sulphurets of noticeable value, which may not appear in the oxidized surface portions of the deposits, but come in later with depth. As already pointed out, it is a simple matter to determine by hand tests and assays whether concentration is desirable or not on any given ore; and, having decided in the affirmative, the practical execution of the work is two-fold: 1st, the actual separation of the sulphurets in the form of clean concentrates; and 2nd, the treatment of the concentrates obtained. As the question of concentration will be treated later on under Part II, and as the concentrates, from their nature, come under the heads 4 and 5 of more effective treatment, it is only necessary here to make some general remarks under the present head.

The process of concentration requires no description, and the machinery used is pretty generally known. It can be safely stated—without going into descriptions of dozens of new machines which, like the pulverizers that come out to displace stamps, are heard of for a little, then drop out of sight again—that where sulphurets are of such value as to make close saving necessary, the Frue vanner and Embrey concentrator are always used in modern mills; but if sulphurets are low grade, and the object is simply to collect most of them for rough working in pans or sale to smelters, simpler and less perfect appliances will answer, such as blanket sluices, bumping-tables, and buddles. It is sometimes objected by inexperienced millmen that the more perfect concentrators require too much skill, or are too expensive to put in place; but the question cannot be disposed of by such superficial reasons; the actual points are, that if sulphurets will pay to save close, it is absurd to adjust the machinery to the men employed instead of choosing the men with reference to machinery which must be used; and again, the matter of cost must be one of expediency, and interest on money invested. There is no difficulty now in engaging men of thorough experience in handling concentrators, and one man can as easily overlook twenty machines as one, and break in other men to the work as well. Of course where profits from sulphurets can only be small, there is no reason for installing an expensive floor of concentrators; and bumping-tables or revolving buddles will answer the purpose. However out of the way a mining camp may be, and however poor the native labor, there is no reason why skilled men should not be employed in directing the minimg and milling; and the company which submits to inferior skill to save paying the necessary salaries, will require a rich mine, and good backing of luck as well, to prevent failure.

The disposition of sulphurets, when obtained by concentration, depends on a variety of circumstances; and in some mines, where certain streaks consist of nearly solid mineral, or where the sulphurets come in smaller or larger pockets easily distinguishable from the bulk of the quartz or other gangue, it is often advisable to pick out at the mine the solid mineral and add this to the concentrates, rather than let it go through the batteries and be subject to the loss in free gold and sliming of the mineral. As a rule, the process adopted for the concentrates will yield a higher percentage than the simple milling and concentrating process, so there is an advantage in adding the hand-selected richer ore of the mine to the concentrates. In certain cases of coarse gold being present in the solid mineral, which would complicate subsequent treatment by chlorination, it may be better to let the mineral go into the mill with the bulk of the ore, as the sliming of the mineral would be the lesser of two evils. Whenever the neighborhood of smelters or cheap transportation allows, it is desirable to sell the concentrates, as good prices can usually be obtained, and credit sometimes received for lead, copper, or iron in the sulphurets. Generally, however, smelting is not available, except as a local treatment simply for the sulphurets, as described under heads 4 and 5, in place of chlorination. Frequently the choice of treatment

will rest between some form of chlorination, and amalgamation after roasting; and in certain exceptional cases even pan or copper-plate amalgamation is necessary after chlorination, in order to save some coarse gold escaping the first process. Chlorination is in most cases preferable to all other processes for the ordinary sulphurets of gold ores. There are various modifications of the process, the advantages of which are simply dependent on relative costs of chemicals and labor, and the quantities to be treated daily.

### (4 and 5) More Effective Processes.

The ores which cannot be economically treated by simple copper-plate amalgamation, with or without concentration, must be relatively richer than the average of free-milling ores—which can perhaps be taken as an average all over the world of some 10 dwts. per ton—or they cannot be treated at all in most mining camps. When an ore, from its contents in silver, lead, copper, iron, lime, etc., is of intrinsic value outside of the gold contents, for other metals, or as a flux for other ores, a very low gold assay may be made profitable; but putting aside the cases in which the nature of ore and proximity of smelting gives a fluxing value, we can divide the gold ores not susceptible of copper-plate process into the following groups:—

(A) Comparatively high grade ore, in which the gold will not amalgamate to a fair percentage, although little or no sulphurets are present.

(B) Ores which contain large quantities of sulphurets.

(C) Exceptional ores, in which the condition of the gold is unknown.

It will facilitate explanation to describe these groups separately.

### (A) Free Ores.

In many of the higher grade gold ores the metal is very finely divided through the rock, and seemingly to this alone is due the excessive loss experienced in the regular process. In some such cases the gold is alloyed with silver, and worth very little per ounce of bullion. The question of fine crushing and of re-grinding has already been touched on, and therefore it is assumed that such remedies have been found insufficient for the ore under discussion now.

After copper-plate amalgamation, the next simplest and most economical process is that of pan amalgamation, which is adopted either on the raw or roasted ore. Usually roasting of gold ores is unsatisfactory as a preparation for amalgamation, and puts part of the gold in a condition most unfavorable for allowing contact with the quicksilver; besides involving sometimes a loss of gold in the actual roasting, at times even to a very marked extent. In roasting some gold ores it is found advantageous to add a small percentage of salt in the charge, but on other ores this addition largely increases the loss of gold by volatilization.

In some exceptional ores, such as described on page 43 where there are practically no base metals present, roasting can be adopted without these ill effects but even then its commercial advantages must be carefully considered. The roasting operation is frequently effective in softening and cracking the hardest rock particles, so as to facilitate grinding in the pan, and consequently improving the amalgamation. This is also found to be the case in preparing a free ore for chlorination, as the gas will better penetrate the particles and attack the imbedded gold when the crushing is not very fine.

The old fashioned stone arrastra, though slow, is an excellent amalgamator of fine gold; and there are circumstances in which this simple and readily built machine is well worth the consideration of the millman on either raw or roasted ores, as giving a greater efficiency than an iron pan.



### Pan Amalgamation.

The raw pan amalgamation is conducted either by the old tank system, or by the modern continuous process. In the former, the crushed ore is run into large shallow settling tanks, which are dug out by hand, and charged into the separate pans; while in the continuous process, the pulp runs through a line of pans and settlers connected by pipes, so that no handling or settling of the pulp is required. The first one or two of the pans in the continuous system are specially arranged for grinding the pulp, as this is usually necessary. The extent to which pan amalgamation will succeed, can be determined only by experiment; and this can be tried by small pan charges in a laboratory pan if a large pan be not available. In these experiments, as in actual work, the use of chemicals should be very limited; with gold very little, if anything, is necessary, and a little lime or cyanide of potassium will generally cover all the requirements of keeping the quicksilver clean. Heating the pans is an important factor. The continuous process offers great advantages in economy of space and cost of working; very little labor is required, and several gold mines in the United States, as well as silver mines, are using the process with marked success. In the case of some gold ores carrying a small percentage of rich sulphurets, concentration is used before or after the pan amalgamation, and materially increases the saving effected. This combination process is especially available for mixed gold and silver ores, and is more fully treated under the head of Concentration, on page 48. After the pulp leaves the last settler, it contains an excess of water for the concentrators, which must be provided for in one of three ways, viz:—by settling in the large pointed boxes; by spreading on a larger number of regular Frue vanners than usual; or by the use of a smaller number of the improved belt vanners, which can handle a greater excess of water than the regular smooth belts, as will be described later on.

### Chlorination.

Pan amalgamation not being available on any given ore of the class under discussion, there remains, broadly speaking, nothing but chlorination. For working a few tons per day of concentrates, the regular Plattner process, with fixed tanks and long exposure to gas, is as convenient and economical as any of the improved processes; because the plant is simple and cheap to erect, and very few hands necessary. The production of the gas is a simple question of relative cost of different chemicals delivered at the mine. When, however, it comes to treating the crude ore of a mine by chlorination, the conditions are changed, and there is a field for improvement over the regular method of chlorination. To work large quantities of ore daily, of a necessarily lower grade than most concentrates from mills, requires economy in crushing, roasting, gas consumption, labor, and time employed. There are great differences of opinion as to the advantages of using gas under pressure, and the best methods of producing the gas and filtering off the solution from the precipitated gold; but the use of revolving barrels in place of fixed tanks offers an economy in labor and time, and makes special watchful skill less important in the whole process than in the Plattner method; so that one of the modifications of the barrel system would be naturally adopted on crude ore for extensive working. In regard to chemicals for production of gas, claims are made of economy by the proposed supply of condensed chlorine at reasonable rates; and the high cost of transportation to many mining districts beyond doubt opens a prospect for this improvement.

Another proposed economy is the use of bromine in place of chlorine. It is asserted by the Newberry-Vautin Company that liquid bromine can be supplied at 25 cents per pound, and that 5 lbs. will suffice for a barrel charge of 1¼ tons. The simplicity of merely emptying a regulation 5 lb. bottle into the barrel, and the nom

inal freight on this as compared with that on 75 to 100 lbs. of chemicals necessary if chlorine is produced on the ground, make this departure also a promising one for the future cheapening of the process. The effectiveness of bromine as a substitute for chlorine has long been known to metallurgists, but cost has, so far, interfered with its application.

At the Mount Morgan mine is the largest chlorination plant in the world. The ore averages as worked, 5 oz. gold per ton, and 1500 tons are worked per week, while the tailings are said to contain only 3 dwts. per ton. The process is by drying, crushing in rolls, roasting, and working in revolving barrels by aid of chloride of lime and sulphuric acid. The total cost of the process, working on this large scale, is about $7.50 per ton; the sulphuric acid employed is made on the ground from imported sulphur. The ore would be commonly called a free ore, but the gold is very finely divided through the rock. It is roasted for about 2½ hours, and is worked in wooden barrels, 5½ ft. by 3½ ft., made of 3-inch sides, and 4-inch ends braced with iron, and taking a charge of 1 ton of ore; using 30 lbs. chloride of lime, and 33 lbs. of sulphuric acid, Sp. G. 1.6, with 80 gallons of water. The gas pressure is not above 20 lbs. per square inch at its maximum development, and is due entirely to gas produced by the chemicals. The charge is worked by slow revolution of barrels for two hours, and is then filtered on gravel and sand beds, and the solution precipitated by filtration through charcoal filters, which are burnt afterwards in a reverberatory furnace. Steam power is used in the works. The proved advantage of pressure in this case is probably due in part to the system of crushing by rolls through a 35-mesh screen, and the absence of sulphurets. The gold is very fine and the relatively large particles of rock are permeated more perfectly by the gas under pressure. On a sulphuretted ore, crushed the same way, the particles are rendered porous by the roasting, and pressure may be quite unnecessary. At the San Sebastian mine in San Salvador a very large Plattner chlorination plant was erected, the ore being crushed wet in Huntington mills; then settled, dried, roasted, and "gassed." The disadvantages of wet crushing and change in character of the ore led to the abandonment of this process. In South Carolina, using barrel process of chlorination without pressure, working 4 tons daily of concentrates containing about 1½ oz. gold per ton, Mr. A. Thies has reduced the cost of the whole process to $3.60 per ton, with an extraction of 95 per cent. of the assay value.

It is particularly necessary in milling to keep as much as possible to processes which have been actually worked out in practice, as loss of time in experimenting and perfecting of details is often very serious, and this must be considered in examining the claims of all new, or so-called new processes. It is also highly important that the mine owner should not be led into hasty conclusions as to the necessity of an expensive complicated process, simply from the results of the first few months' working of a mill, when selected rich ore is worked, perhaps inexperienced millmen employed, and no ingenuity has been exercised in modifying the details of the regular process to the peculiarity of the ore.

### (B) Sulphuretted Ores.

With these a larger field of treatment is opened by the admission of smelting processes of various kinds. Generally the pan amalgamation process must be preceded by roasting. In the Colonies grinding and working the raw partially concentrated sulphurets in pans is practiced, but in the United States this process has entirely gone out of use, being displaced by smelting and chlorination, rendered possible by the development of the country and by more perfect concentration. Some sulphurets contain their value in comparatively coarse free gold, which grinding will liberate



and mercury attack; but most of the base metal sulphides in gold ores will only yield a small part of their gold contents to such a process, and the loss of quicksilver is great. Even where still in use, this process often has its chief excuse in an imperfect concentration, and would be better superseded by the close saving of higher grade clean concentrates, properly treated by chlorination or some modification of the smelting process.

As sulphuretted ores may comprehend all proportions between the sulphides and the gangue, and as treatment often depends on the relative proportion of the two, it is better to divide them into two classes, which must necessarily be somewhat arbitrary, but will at least facilitate description. The following divisions will therefore be taken:—

(1) Concentrating ores.
(2) Non-concentrating ores.

No sharp line of distinction can be made by mere percentage of sulphurets between these two classes, because average value and local cost of treatment enter into the calculation; but, roughly speaking, ores containing over 40 per cent. of sulphurets are not fit for concentration. Frequently an ore which will average 20 to 50 per cent. of sulphurets as coming from the mine, is far better divided by hand selection into rich mineral of the class (2), and poorer ore for concentration. For instance, in a mine where seams and pockets of solid minerals occur, it may happen that 100 tons just as mined will contain 20 per cent. of sulphurets, and yet by a simple hand-picking this can be separated into 20 tons of 75 per cent. sulphurets and 80 tons of 6¼ per cent. sulphurets. Where this can be cheaply done, it is far better than submitting the whole 100 tons to the cost and losses of concentration, and it also renders possible a more expensive process than the original ore could sustain.

### (1) Concentrating Ores.

The gold in such ores is generally partly free and partly combined with the sulphurets. In speaking of the gold as combined with the sulphurets, the miner's sense of the term, rather than the chemist's, is intended. It is held by many authorities that the gold is seldom or never found actually in chemical combinations—excepting in some antimony and tellurium compounds—but is in an exceedingly fine state of division mechanically intermixed with the base metal sulphides. But to the millman this view of the case is without importance, because as a matter of fact the mechanical division is so perfect, and the difficulty of grinding and avoiding the influence of base metals so great commercially, that roasting is necessary to free the gold. The term "combined" is therefore used in this article as a millman would use it, i. e. as meaning such a condition that practically the gold is only freed by roasting or action of acids. In this connection it may be worth while to remark that the advocates of new processes of gold extraction from this class of ore, based on assumed metallic condition of the metal itself, often fail to appreciate the fact that the *mere* preliminary impalpable-grinding is itself equivalent to a commercial condemnation of the process, by necessitating use of grinding machinery, which greatly increases the cost over ordinary processes.

If the gold be partly distinct from the sulphurets, as shown by an ordinary degree of crushing—say to 40-mesh—and the percentage of sulphurets does not exceed 10, there is hardly any question at all but that stamps, copper-plates, and Frue vanners, will cover the process required and give the best commercial results; because this is the process now used by the best and most successful millmen all over the world. Of course, if it be proved that the sulphurets, when collected in a clean concentrate free of sand—as they can easily be—do not assay enough to leave a profit on

further and more expensive treatment, or on shipment to smelters, it is useless to add concentrators to the copper-plates. The sulphurets in this case either run to waste or are roughly saved by crude and cheap concentrating appliances for some rough treatment like raw panning, which will yield a trifle over cost of operation.

As a general rule it can be said that if the percentage of sulphurets does not exceed 10, it is better to stamp fine enough for copper-plates and Frue vanners at once, for simplicity and economy; but when the percentage runs much above this, a coarser crushing and use of jigs will be advisable; the relative advantages of the two processes will be more fully treated in the article on concentration of ores, as well as of a combination process by which stamping with coarser screens and treatment by both jigs and vanners is advisable. Most gold ores, even when heavily sulphuretted, will not stand a very coarse crushing and jigging, unless the coarser jig tailings are re-ground, because the rock particles still contain too much gold. In such cases, expediency is the only guide in the choice between compound treatment and the probable increase of loss by sliming when the ore is stamped fine enough at one operation, and it will be shown later how this last danger can be reduced, by proper care, to a point lower than is usually supposed.

The concentrations produced require of course a special treatment; and this will come under the next head of Non-concentrating Ores, those which are already concentrated by Nature. It may be mentioned, however, that there is no excuse for producing unclean concentrates with modern machinery; and it is clearly advisable that a material which is to be treated by a more expensive process should be as highly concentrated as possible, free from valueless rock as nearly as may be. In California it is not unusual for a contractor to put in concentrators under agreement that they will save 90 per cent. of the mineral freed by crushing from the gangue, and produce concentrates not containing over 10 per cent. of sand. In a properly running mill under good management the concentrates are delivered almost clean, say with 3 to 5 per cent. of sand; although there are some partially oxidized ores in which an iron sand of intermediate specific gravity between mineral and rock is allowed to pass over with the former, on account of its gold value.

### (2) Non-Concentrating Sulphuretted Ore.

The concentrates obtained in a mill will be included with the heavily sulphuretted ores selected from the mine under this one head; the only difference being that one is already crushed and the other is not. To bring both classes to the same condition, reference will first be made to crushing the crude ore. This is best done by rolls, and dry, as a preparation for roasting. The modern designs for crushing rolls differ materially from the old Cornish rolls. They are now constructed of compact form on a low bed plate, driven independently by belt pulleys without the use of gear wheels, and at a speed of 100 to 150 revolutions per minute; while the shells are made of forged steel when fine crushing is necessary, so that the faces can be turned up occasionally and kept true, which is an essential for large capacity. The degree of fineness to which crushing must be carried depends on subsequent treatment; for smelting, it is unnecessary to crush finer than will secure the necessary elimination of sulphur in the first roasting; for chlorination, finer crushing is required, both to secure the dead roast and insure the solution of the gold. There are some ball and roller grinding mills which may be used for the dry crushing of rich ore, because usually small quantities only are involved, and strict economy is not important; so that, while such mills are by no means adapted to superseding stamps, as their inventors claim, they have a limited sphere of usefulness for grinding small quantities, and for this special purpose they have their advantages of simplicity over crushers,



rolls and screens, combined in a plant. Where the grinder does not have a fixed screen so as to deliver at once a sized product, as, for instance, with rolls, it is necessary to screen outside and return the coarse to the grinder. Usually this is done by revolving screens of circular or hexagonal section; but of late a separator which is very simple and effective, using currents of air for the sizing, has been used with success. This classifier is known as Mumford and Moodie's separator, and is used, both in England and the United States, in connection with Buhr millstones, rolls, and centrifugal mills. An effective machine of this character has the advantage over screens of less wear and tear, and less interruption to work from breaking of wire cloth and discharge of coarse pieces.

The processes which can be used on the class of ore now under consideration will be the following:—

(1) Chlorination.
(2) Smelting.
(3) Amalgamation.

It is not worth while considering the claims of chemical and other processes for extracting the gold, as these notes are intended to cover simply what is known and proved, not what is claimed or in process of being proved.

### (1) Chlorination.

A good deal has been written of late on this subject, and it has been the basis of several new processes which depend for their success on modifications of procedure and the production of the essential element, the chlorine. The general points of the process have already been treated under the head (A) Free Ores, so that it is unnecessary to dwell longer on this subject. In most mining camps it is the process most likely to be adopted on concentrates and hand-picked sulphuretted ores. When silver is present in quantity to justify the extra treatment, a double leaching is employed. The ore is roasted nearly "dead," then a small percentage of salt is added and the silver is chloridized, the sulphur is all driven off, and the ferrous and cuprous sulphates are oxidized. The ore is then "gassed" as usual, with chlorine, and the gold leached out. The residue is again leached with hyposulphite solution, to dissolve the chloride of silver, which is precipitated as sulphide.

### (2) Smelting.

The Smelting process, either completely or partially carried out, offers an alternative to the chlorination process which has not been sufficently considered by millmen hitherto, probably because it is a distinct business in itself, and its capabilities are only appreciated by educated metallurgists; but at the present day the services of good smelters are so easily obtainable that there is no reason why this branch of reduction should be neglected where conditions make it available, for chlorination also requires a special experience in the man in charge of this department. The application of the smelting process to gold ores are covered by the following modifications, to be separately described:—

(*a*) Complete smelting to silver lead bullion.
(*b*) Concentrating smelting to iron matte.
(*c*) Concentrating smelting to copper matte.

Practically these modifications are simply determined by the character of the ores, and differ more in products than in operation.

### (a) Lead Smelting.

This is an operation which can only be economically carried on under very favorable conditions of lead ore supply, fuel, and transportation at reasonable rates for the base bullion; and therefore would be available only where smelting at a distinct operation is profitable, regardless of the special gold ores under consideration. It is possible, however, under certain circumstances, to employ this operation to a limited extent even at a comparatively high cost, where some little lead ore is available. In such cases the concentrates and richer sulphuretted ores are roasted, and mixed with lead ores, fluxes, and the litharge of previous runs, smelted to lead bullion, which is cupelled to gold and silver bullion, and the litharge is used over again for the smelting. This process properly conducted, though expensive in appearance, may be made available on rich ores and concentrates, and will yield a very high percentage of the value. Where wood is abundant this is used for the roasting, and charcoal is made for the smelting. With excessive charges for transportation, and rich material in small quantity to work, and a supply of lead to make up losses at a cost that is not excessive, the intermittent lead smelting is practicable.

### (b) Smelting to Iron Matte.

This operation consists in partially roasting the rich ores and concentrates, and smelting with the necessary fluxes for a fluid slag, with the production of a rich iron matte containing the gold and silver, and some lead and copper if sulphides of these metals exist in the ores. The operation is simple, and with cheap fuel is reasonable in cost. As the roasted material will consist largely of oxide of iron, and usually contains quartz in greater or less quantity, the fluxing is not generally a difficult matter.

Wood and charcoal can be used as fuels. The roasting in some cases can be done in open piles sufficiently for the coarse selected ore of the mine, while the concentrates are worked in reverberatory furnaces, both being smelted together in a stack furnace for the matte production.

The disposal of the enriched matte must depend on circumstances. Frequently it can be run up to so valuable a grade as to justify shipment, even at high rates, to large smelting works for reduction; or it can be crushed, roasted and chlorinated.

Of course, the use of this process as a mere preliminary to chlorination can only be justified where its cost is less than that of the latter; and there are mining districts where chlorination on a large scale must be too expensive on the crude ore, but would be justifiable on a few tons daily of very rich material.

### (c) Smelting to Copper Matte.

This is precisely the same as the smelting just described for iron matte, except that the presence of copper gives a distinctive character to the product, and may add to its commercial value. Both in this and the preceding process, the matte can be enriched still further by a second partial roasting and smelting, which in the case of copper-bearing ores has the advantage of increasing the copper contents as well as the gold value of the product. In many cases the copper may help to pay or may wholly pay the cost of transportation and refining of the matte.

It is not necessary to go into details of the smelting operation, which is fully described in various text-books; the only point under consideration now is its practicable application to gold ores. There is as great a difference between the cheapest and most costly working by the chlorination process in the United States, as there is variation of smelting costs per ton—viz., from $4.50 to $20.00 per ton of 2,000 lbs.—



but of course the quantities handled in the cheapest working smelting plants are larger than those worked in any chlorination establishments.

The advantages of the smelting processes are as follows:—If silver or copper be present it can be utilized without extra expense or change in the process; the plant is simple and can be started very crudely and economically in furnaces built on the ground for experimental results; and the process is based on an exact science. It is not necessary to experiment as to the condition of the gold in the ore, an analysis of an average sample would enable an educated smelter to state exactly what could be done with it, and what fluxes would be useful in its reduction; the items of fuel supply, labor, and transportation, would enable an estimate to be made of the cost.

### (3) Pan Amalgamation.

The sulphuretted ores and concentrates can, as a safe general rule, be considered as not adapted to amalgamation without a previous roasting. In some few cases, where the gold is comparatively coarse, a sufficient proportion of it can be extracted by raw pan amalgamation to pay a profit on the operation, and this process is used at places in the Australian Colonies, usually after a crude process of concentration, which itself involves considerable loss of fine material and the production of unclean concentrates; and in some few cases, the value thus extracted is to an appreciable extent in the form of amalgam, lost before concentration. Generally speaking, therefore, it is safe to say that raw amalgamation is unadvisable on the material now considered.

The dead roasting of sulphurets as a preparation for pan amalgamation, simplifies and improves the process by preventing the loss of quicksilver consequent on working raw sulphides, and by increasing the percentage of gold saved; but it is not so successful as generally supposed, nor as theory would promise. The operation of roasting—while it apparently frees the gold from its combinations, increases perhaps the size of the gold particles, and eliminates the objectionable sulphur compounds—seems to have a bad effect on a large part of the gold, putting it, superficially at least, in a condition very unfavorable for securing contact with quicksilver. The extent to which the gold is thus affected varies curiously in different ores of apparently similar composition; and the conditions of roasting have also a great influence on the result. For the amalgamation itself of the roasted ores various methods are recommended. One process used in the colonies is by working with large excess of quicksilver and little water, and apart from contact with iron. The effect of grinding in iron pans seems in some cases much less beneficial than when amalgamation is conducted in stone arrastras. The use of gold amalgam in place of quicksilver, and the avoiding of contact with iron surfaces, was found most beneficial in experiments conducted by Stetefeldt in Mexico, and a high percentage was extracted from a low grade ore. On the other hand, experiments on many gold ores in the New York Ore Testing Works gave unsatisfactory results by all these processes after roasting in a small reverberatory furnace, and nothing but chlorination was found effective when the metal was rich in gold. On pages 16 and 43 reference is also made to this subject of roasting gold ores.

On any given ore, experiment alone will show how high a percentage may be extracted, and the best conditions of heat and time in the roasting; but it would probably be fair to say that on material assaying about 2 oz. gold to the ton, this process is seldom advisable; and even below this value the practicability of chlorination or concentrating smelting should be first considered.

### (C) Exceptional Ores.

There are occasionally met with ores of gold in which the gold is not free so far as tests indicate, and yet there are no sulphurets present. These ores are usually oxidized in character, changed from their original form, and contain chloride of silver in addition to the gold. Some of these ores, when leached with hyposulphite of soda, yield a large portion of the gold as well as the silver to solution; and this fact would indicate that the gold exists as a chloride, either combined with the silver as a double insoluble chloride, or mechanically protected by the latter from leaching out by natural water drainage in the mine. Such ores are uncommon, but have been worked to some extent in the United States by leaching raw with hyposulphite of soda, and then concentrating for the fine carbonate of lead also present, and its combined silver. Concentration and pan amalgamation would probably be effective on such ores.

The presence of tellurium in gold ores sometimes complicates the question of treatment. If in small quantities in the presence of sulphurets, it must be considered as a part of these in the general plan of treatment. If the value of the ore lies mostly in tellurides of gold and silver, with little or no sulphurets present, the most successful method yet found is by the selection of the rich ore, and concentration with peculiar care, and double treatment, of the low grade ores. Both rich ore and concentrates are then so valuable that a perfect smelting process, or shipment to smelters is advisable.

If to the above two classes of exceptional ore is added the class described under (A) Free Ores, it will be pretty safe to say that the remaining gold ores of the world so far as yet worked do not justify the use of the terms "rusty" and "float" gold as commonly employed, but that these are simply picturesque titles for necessary loss, imagined loss, or avoidable loss. The term "float" gold is especially misleading, and "fine gold in suspension" would in all cases be more correctly descriptive; a very large piece of gold, if dry, will "float" on the water, and a microscopically small piece wet, will sink. It is not too comprehensive to say, considering the very few cases in which the term "rusty" gold is really justified, that the more a millman uses the two terms "float" and "rusty," the less experience and skill will be found to possess.

# CONCENTRATION

OF

# GOLD AND SILVER ORES.

PART II.

The credit of systematic and scientific concentration of ores is, unquestionably, due to the Germans; but as the working of gold and silver ores without regard to saving of baser metals is practiced in Germany to a very limited degree, and that too in a developed country with cheap labor, fuel, and transportation, it follows that German practice is without authority in this branch; while circumstances, and a great variety in ores, have made the United States the natural nursery of this class of work. The following advances over German methods may be noted in the United States: (1) Direct coarse stamping and classifying over jigs and slime machinery. (2) Direct fine stamping over improved slime-working machinery without sizing. It is not necessary to consider the essentially English methods of concentration as still existing in Cornwall; for ill-adapted as they are even for good work on tin and copper ores, they are much worse, and in fact quite out of the question, on valuable ores of gold and silver; and no one of any broad experience ventures to defend the system of handling and re-handling, with consequent production of ill-defined "heads," "middles," and "tails," of the fixed buddles, strakes, and frames still employed.

On lead and zinc ores, the essentially German system of concentration is employed in the United States, i. e. rolls, sizing screens, jigs, and slime machinery. On Lake Superior a special process has grown up, from the character of the native copper ores and conditions of the country. Steam stamps of a capacity of 200 to 250 tons daily each, hydraulic classifiers, jigs of a somewhat improved type, and revolving buddles, constitute the machinery employed. The process has been criticised a good deal by concentration men bred upon German science, and charges of excessive sliming of the copper and imperfect sizing for the jigs, have been made against the system. But there can be no reasonable doubt that the copper men have selected a type of plant which yields them more profit than any other would; and mining is a business carried on more for the sake of profit than for the advancement of science.

It has been assumed until quite lately that the apparently unscientific process of steam stamping for concentration, though proved commercially successful on native copper, would stop there; but the enterprise of the Anaconda Copper Company, of Montana, has again changed the basis of calculation.

This company had an immense plant of crushing rolls, sizing screens, jigs, and buddles, for working its sulphide of copper ores, and with a capacity of 1000 tons per day. The wear of rolls and sizing screens, and complicated nature of the whole

plant, led to experiments by the Lake Superior system; and the financial results were so good that an entire new plant, based on the steam stamp system, was built, and now has a capacity of some 2000 tons per day. Further than this, a steam stamp was put in for crushing silver ores at the same works for pan amalgamation, and another steam stamp was erected in the Black Hills for working gold ores, and both of these are claimed to yield good commercial results.

In part explanation of the reason for the improved commercial results of the process, it is stated that while the stamp does make a greater percentage of slimes than careful crushing by rolls, the difference is very largely made up in the great attrition of mineral which takes place in revolving screens, launders, and the elevating and returning of material for the rolls. The stamp delivers through a screen, so that a sized product is immediately obtained; and all the wear of revolving screens and elevators is saved. There is also a quicker and more immediate delivery by launders to the concentrating machines than by the roll system, and attrition of mineral is diminished from this cause. The steam stamp, by its rapid and enormous delivery, makes less slimes than gravitation stamps, as proved in crushing both ways on the same ore for pan amalgamation. In Australia, steam stamps have been erected for silver-lead ores, and the Lake Superior system adopted in full, but the results of this departure from accepted methods have not been published.

In the last few years the concentration of gold and silver ores by a direct process, without sizing, after fine crushing by stamps, has become the established process for a very large variety of ores in the United States, and when properly conducted is as perfect as any mechanical process can be. The following notes based on many years' experience in the United States, and on several years' experience in testing-works treatment of ores from all parts of the world, are intended as suggestions for special cases, and are warranted by results obtained in practice in the directions indicated.

As reference will be made to settling boxes and hydraulic sizers, which are outside the experience of many millmen, some description will first be given of their construction and use.



## SETTLING BOXES.

These are for the purpose of settling the sand and mineral in suspension in a flowing current, so as to run off the excess of water not needed in subsequent treatment of the ore, and to deliver continuously a thicker pulp from the bottom of the pointed box. The regular settling tanks, used in silver mills before pans, and for retaining tailings in some places, are well enough known: but these require digging out, and changes of the pulp flow from one to another; they are therefore useless for the purposes of a continuous working process. Where tailings are caught in large pits, it is frequently seen that the settling is not so perfect as the large size employed would warrant, and this is due to the surface currents, and channels cut in the deposited material when it fills to the surface. The large pointed boxes, if properly built, are deserving of more attention than they have yet received, for many purposes. Where water has to be used in part over again in a mill, a series of these boxes will do far more effective work than pits or settling tanks, and require no attention or labor; they will deliver a small stream of thick concentrated pulp at the bottom and give an overflow of almost clear water at the top.

To make them effective, however, there are several points which must not be ignored; these are:—

(1) Proper angle at bottom to insure descent of slimes—not less than 50 degrees from horizontal.

(2) Proportioning of water inflow to capacity.

(3) Avoiding too small a discharge opening at the bottom.

(4) Preventing surface currents from the inflow to the overflow end.

(5) Preventing ingress of coarse sand, chips, and other obstructing matter.

On plate 281 will be found complete details and dimensions of a large pointed box, which is of sufficient size to handle the pulp and water from 5 or even 10 stamps under some circumstances. It will be noticed that a partition extends across the box near the inflow end, dipping well down into the water, so as to cut off water currents and insure a mixture of the incoming pulp with the whole mass of water in the box; in the absence of this, currents of muddy water will be seen flowing through the clearer mass direct to the overflow end. A frequent mistake of millmen in making flat settling tanks, is to assume that length is all-important in settling slime, and to put in too many zig-zag partitions so as to force the water currents to take as long a course as possible. This frequently destroys the very advantages sought, by making a comparatively rapid surface current in narrow channels. If slime will remain in suspension in a given current of water for 12 feet, it will do so nearly as perfectly for 50 or 100 feet. The proper means to insure settling is to diminish the speed of current, not to lengthen its course. For example, to put the combined pulp from 10 stamps over two of the pointed boxes shown in Plate 231, placed one after the other, would be nothing like so effective as dividing the pulp and putting the product of each 5 stamps over a separate box. To put zig-zag partitions across the settling box, would lessen its efficiency for perfect settling, by determining relatively rapid cur-

**PLATE 231. CODE WORD: ASTER.**

Fraser & Chalmers, Chicago, Ill.

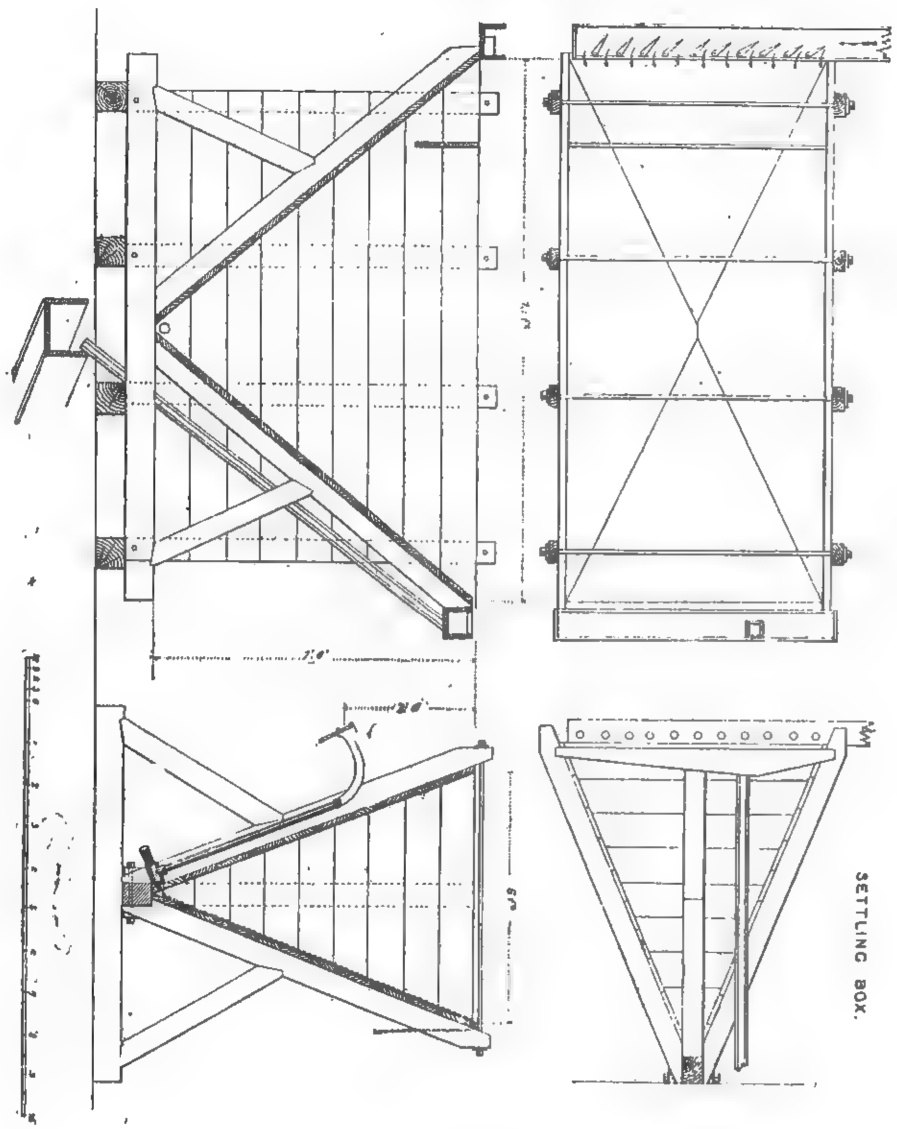
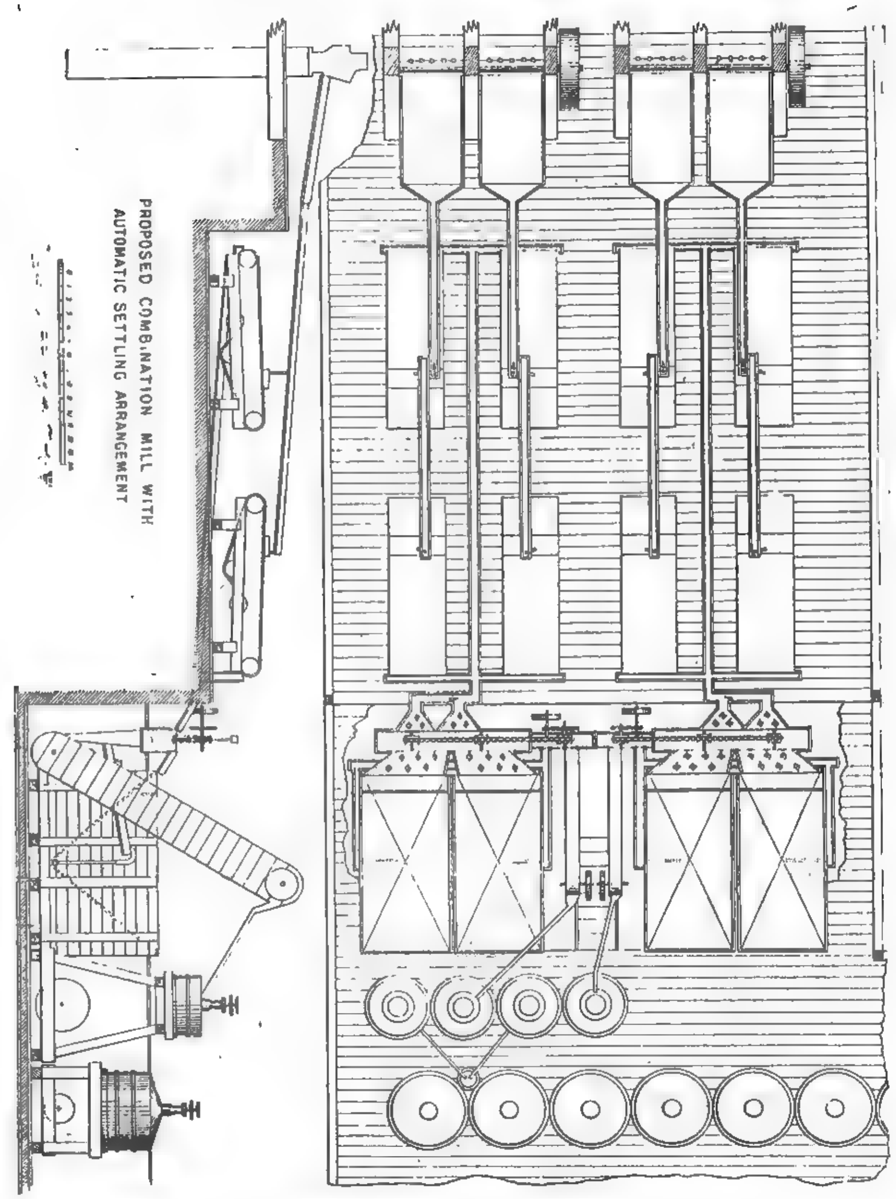





**PLATE 477. CODE WORD: ROGREGATIM.**

Fraser & Chalmers, Chicago, Ill.




DETAILS OF SETTLING ON PLATE 478, PAGE 33.

rents in fixed directions, instead of producing an incorporation of the incoming pulp with the mass of water, and the consequent overflow at the distant quiet end by mere rise of level.

The capacity of the box shown will depend, of course, on the perfection to which settling has to be carried. For concentration, it is by no means essential that the overflow should be clear water, because any mineral which will not settle in a reasonable time in still water, will be small in quantity, and only very partially saved by concentration in any case. Where, however, it is a matter of settling for pan amalgamation, the greatest care is necessary, because the chlorides and sulphides of silver are apt to be exceedingly light and flaky in form.

In the case of the application of pointed boxes to settling for pan amalgamation —which is feasible under proper conditions, and would be most advantageous as compared with square tanks—it is necessary to take out, in a separate dryer form, the bulk cf the heavy sand, so as to insure by its mixture with the liquid discharge of the pointed boxes the requisite thickness of pulp in the pan charge. Mr. M. P. Boss has suggested for this purpose that the pulp should pass over a flatly-inclined traveling belt with flanges, from which a scraper would take off the thick deposit delivered by its slow revolution; while the slime would flow off the lower end and into the pointed box, the lower discharge of which would join the thick sand of the belt for the direct continuous treatment in the pans. Another suggestion of the same gentleman is to use a small box with screw conveyor to discharge the thick pulp before the slimes flow to the large pointed box.

But a still simpler plan—with the intermittent system of amalgamation—is to use two small square tanks for the pulp to pass through before reaching the pointed boxes, so as to catch the heavy sand. As soon as one tank is full, the pulp is turned to pass through the other, while the first is dug out, after a short draining. In this way the labor of settling and digging out all the slimy pulp is avoided, and the heavy part easily handled is caught at once. An examination of the settling tanks in many silver mills shows clearly that the operation is not so perfect as to make it dangerous to change the system, and the large boxes described will certainly give as clean an overflow with much saving of labor. With a proper distribution of pulp to a number of boxes—not the whole pulp through a series of them—very close work can be done. At the Montana Mines, 10 boxes, of the size shown on Plate 231, were put in by the writers, and received the settler discharge from 50 stamps handling 105 tons of ore daily, together with the great excess of water resulting from amalgamation, and these did excellent work with almost clear water outflow. The system was adopted as a preparation for concentration; but owing to the irregular settler discharge—alternations of rushes of pulp and then little or no flow—and also to the proved advantages of concentration before amalgamation, the works were soon changed and the pulp delivered direct from stamps to the vanners. Enough however was accomplished to prove the complete efficiency of the boxes, and to justify the conclusion that, with proper arrangements, a great improvement could be effected over the tank system of settling for pans. In working out the details for a mill not using the continuous process, the storage of the continuous flow of thickened pulp between charges of pans would have to be considered, and might be met by elevating the pulp to a few large agitators with slow motion to prevent packing, and with a hose discharge from the bottoms to fill the pans in rotation, while the heavy sand from the small tanks would be shoveled in to give the right consistency to the pulp. To insure a perfect settling of the valuable silver slimes will require no less than one large box to each 5 stamps; and the width of the boxes placed in a row side by side would not occupy a greater frontage than that of the stamp batteries as ordinarily arranged. Of course there is no reason why the boxes should not be built still larger than shown, if it be desirable



to limit the fluid discharge to as few openings as possible. It has been proved by the adoption of the Boss continuous system that less water can be used in batteries, and a consequent thicker discharge may be obtained, by proper regulation of mortars, than is usually the case in silver mills. For the continuous process there can be no serious difficulty in settling by the process described, after concentrators are used. One advantage of the continuous discharging pointed boxes over shallow tanks in the matter of settling is that in the former the fine slimy pulp keeps settling continuously towards the bottom; while in tanks, there being no discharge at the bottom, the pulp gets thicker and thicker, the level of it rising steadily towards the surface, and being moved towards the overflow end by the incoming pulp flow, as soon as it gets sufficiently high. A sketch is given on Plate 477, page 29, of a proposed mill for the use of concentrators before the continuous process of amalgamation; and on Plate 478 some of the details of the settling arrangement are suggested. This plan, with some modifications, perhaps, as to dimensions—or the use of a traveling belt and scraper—can without doubt be made successful as a substitute for the old style of settling tanks, by use of reservoir agitators tor the charge system; or for direct delivery to the first pan of the Boss continuous process. The long narrow tanks with inclined bottoms, shown in the plan above the settling boxes, are provided with an automatic scraper discharge for the coarse sand, which falls, together with the pulp discharge of the boxes, into an elevator; which last could be dispensed with, of course, if the fall available on the mill site were sufficient.

It is of great importance, this subject of settling for pan amalgamation; because there can be no doubt of the advantage of concentrating many gold and silver ores before they are worked in pans. These advantages may be stated as follows;—relieving the pan from the working of sulphurets, and therefore reducing the necessity of grinding; diminishing the chemicals used and diminishing the loss of quicksilver; also, in some cases, a decided increase in gross yield per ton, from the fact that concentration after amalgamation is always imperfect as compared with the same directly after stamps.

The discharge at the bottom of the pointed box must be regulated in size by reference to the quantity received and thickness of pulp needed. With a large box, as shown, and consequent high head of water pressure, a syphon discharge must be used; otherwise a very small opening, liable to frequent choking, would be necessary. A convenient discharge is that shown in Plate 231; a short nipple of 1¼-inch pipe, with a tee of the same, and an upright pipe about 8½ feet in length, to the upper end of which a 2½ foot length of 2-inch hose is attached, with a sliding gate-tap at the end, similar to what is known as a molasses tap; or the hose can be fitted into a small square box with an opening covered by a sliding gate in front. The advantage of the rubber hose is, that by raising or lowering the discharge end, the pressure from head of water can be regulated. Usually 2 feet to 3 feet difference in level will insure good discharge. The reason for a tee in place of an elbow at the lower end of the pipe is to allow of emptying the tank when inflow ceases, so as to prevent the box from packing solid when the level of discharge is reached; also to allow of removing obstructions to flow; and also to keep an opening for continuous discharge while the box is first being filled, until the water-level reaches the top, when the syphon tap can be opened. The end of the tee is closed by a wooden plug when the box is in operation.

To prevent chips and other foreign substances from getting into the box and choking discharge, it is a good plan to stretch a piece of wire cloth, (about 20-mesh) across the box from the partition to the inflow end, so that the distributing launder discharges on it. The rest of the box, from the partition to overflow, can be covered by loose boards to prevent anything dropping in from above.

Another point to insure good work is to let the pulp evenly over the full width of the box, and with as little agitation as possible. The distributing launder, shown in sketch, has a number of 1-inch holes bored at intervals in the side, and close down to the inside bottom. Between the holes adjustable pivoted buttons are placed, so that an even distribution is made by deflecting the pulp through the various openings.

The overflow is produced by cutting down the end board of the box a little below the level of the sides. The end should be perfectly level, so that the overflow occurs as an even thin sheet of water over the full width; it is well to bevel the outer edge of the end board downwards, so that a sharp edge is exposed to the water inside; and a launder is nailed under the lip so formed, to carry off the overflow water.

As a means of clearing any temporary obstruction of discharge opening in the bottom, a light chain can be attached by a staple to the inside end of the wooden plug used in the discharge tee. The chain passes through the nipple in the bottom of the box, and up to the top of the latter, where it is fastened, to prevent it from dropping back, and with sufficient slack to allow of the wooden plug being withdrawn about a foot. By working the chain up and down, any obstruction is cleared, and the flow again started.

To start the box in operation, the wooden plug is first removed from the tee below, which is either left open or a half-plug put in to diminish the discharge and shorten the time of filling. The pulp is then turned in, and as soon as the box is full and overflow begins, the tee is plugged up and regular discharge begins by the syphon tap. Or the box can be filled first with clear water, both discharges being closed, and the syphon tap opened as soon as the pulp is turned in above. In case the pulp flow ceases, from stoppage of stamps or other cause, clear water is at once turned into the box to supply its place, until all the sand and slime is delivered from the box; or, if loss of pulp is not important, and water scarce, the plug is removed from below and the box emptied. Failing one of these precautions, the box will pack solid with sand, and give much trouble to clear and start again. The running in of clear water is most to be recommended, because it insures the box being kept wet, so preventing any leaking; and, further, no delay occurs in again starting work by the necessity of filling the box before closing the tee.

The uses of the pointed settling boxes can be described generally as one of two operations.

(*a*) For the purpose of obtaining a clear overflow of water to be used over again where that article is scarce; the advantages over square tanks or pits being that the labor of digging out and loss by evaporation are avoided, while space is economized.

(*b*) For running off the excess of water introduced into a pulp—by crushing, sizing, amalgamation, or concentration—so as to produce a thickened pulp for concentration, amalgamation, drying for subsequent treatment, or storage as in the case of concentrates.

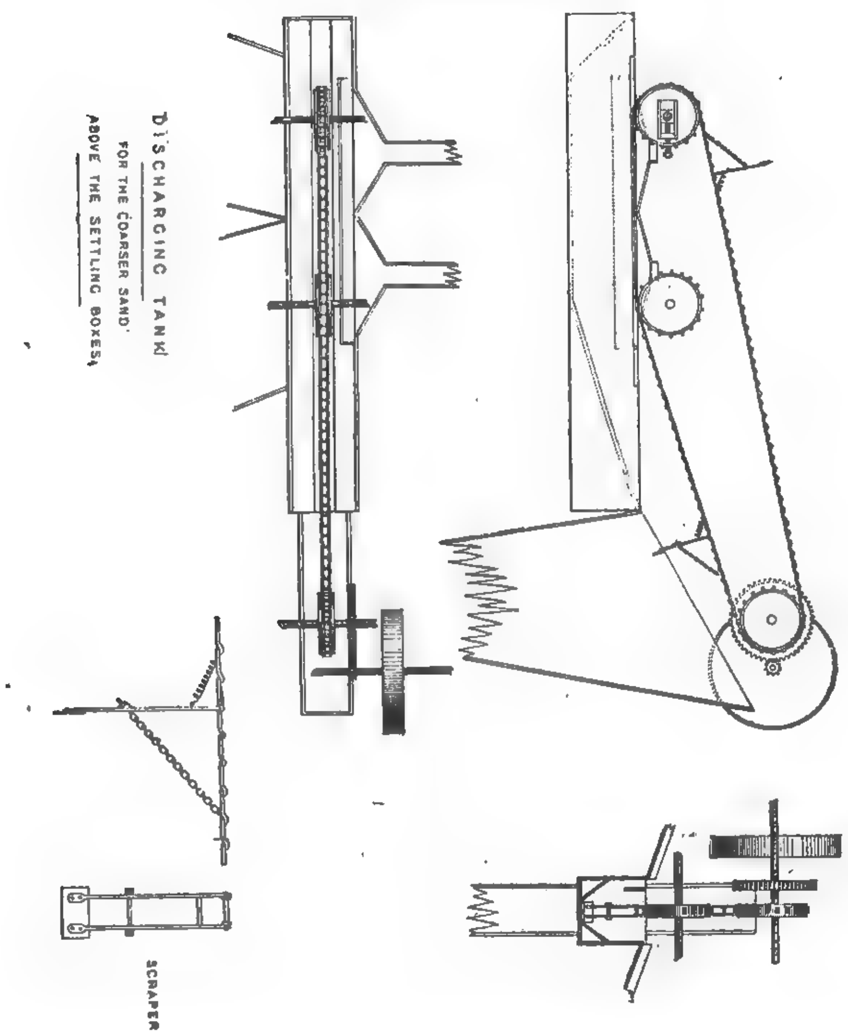
### Hydraulic Classifiers.

It is well known that if a stream of unsized pulp be made to flow through a small pointed box with a smaller discharge at the bottom than the inflow, a certain concentration occurs, the lower discharge containing more coarse sand and heavy mineral than the overflow portion. Such a separation is, however, very imperfect, because the lower discharge must contain the slimes and muddy water which constitute the transporting current for the heavier particles. The object of the hydraulic classifier is to substitute a stream of clear water for the muddy current, and thereby force all



**PLATE 478. CODE WORD: ROGREGNA.**

**Fraser & Chalmers, Chicago, Ill.**




SEE PLATE 477. SCRAPER IS SHOWN TO A LARGER SCALE THAN DISCHARGING TANK.

the slimes to accompany the overflow. The most perfect way of accomplishing this on fine material is by making the clear water pipe itself, under a fixed head, the conduit for the coarse material. On Plate 475, page 36, will be found descriptions of this apparatus, the dimensions of which can be varied in accordance with the size of largest particles of pulp, increasing the area as the material becomes finer and more difficult to settle. The operation is based on the end discharge of the water-pipe being less than the quantity of clear water admitted by the valve, and, as a consequence, there being an upward current of clear water into the settling box. Under this condition, no muddy water can discharge below, but only the particles of ore which have weight enough to drop through the ascending current and into the pipe. By a simple regulation of the valve and its resulting volume of upward current in the box, all variations can be attained, from a clear water discharge accompanied by a few of the heaviest particles of the pulp, to a muddy water containing the large bulk of all the heavy particles. The sliding partition assists the settling, by forcing the pulp to take a downward turn, and so preventing a rapid surface current across the box to the overflow. The clear water must be delivered under a fixed head, to insure uniformity; and this head should be low—very little above the water-level in the classifier—because a high pressure necessitates a very small discharge orifice for the coarse, with consequent liability to choking, or a great excess of water in the discharge.

On Lake Superior, the pulp flows direct from the coarse screens of the steam stamp through a series of double V-trough classifiers, carrying the pulp in the inner one, and clear water in the outer, with openings at intervals between the two, so that the coarse particles drop first into the clear water-trough, and thence, by stops and openings, are discharged to the different jigs. The system is wasteful of water, and less perfect in results and convenience of control, than separate boxes with independent water-pipe supply. On Plate 475, Fig. 3, the arrangement of this separator is shown.

The trough classifier shown on Plate 475, Fig 2, is a great improvement on the Lake Superior double V-trough separator, and was first suggested by Professor Richards, of Boston, and perfected by Mr. Coggin, of the Calumet and Hecla Mill. It will be seen that this trough contains a succession of depressions or boxes, and the clear water is introduced by pipes which have no connection with the discharge openings, but have their delivery ends directly in front of the latter. The valve of the clear water pipe is opened until more water is delivered than the opening in the box will discharge, and in this way an upward current of clear water is caused in the box full of flowing pulp. The action of this classifier can be easily understood from the drawing and previous description. From each opening in a succession of boxes, with proper clear water regulation, a descending series of sizes of ore particles can be obtained for the different jigs. In each box a short partition is put across, to prevent the pulp rushing through as a surface current; and also a small shield is placed horizontally above the delivery end of the clear-water pipe, so as to break the upper current, and cause a more general mixture with the mass of pulp in the box. This is patented, and is known as the "Calumet" separator. It has been found so successful that 72 of this style are now in use in the Calumet and Hecla Mill, handling 3,000 tons of ore daily, and with marked improvements in results over the old style trough separators they have displaced. One of the separators of the size shown will treat 50 to 60 tons daily of the Calumet ore, after coarse crushing by the steam stamps, delivering 4 sizes of product to the jigs and using 700 to 800 gallons of clear water per ton of ore. To admit readily of some experimenting in the distance between the end of inlet pipe and the discharge opening, a stuffing box is first used, which can be changed later for a fixed elbow on the inlet pipe.



The discharge from one of these separators in the Calumet Mill is approximately as follows:

| | | |
|---|---|---|
| From No. 1 spigot (¾ inch) | 20 | tons coarse—heavy. |
| " 2 " (¾ " ) | 12 | " coarse—light. |
| " 3 " (½ " ) | 8 | " medium. |
| " 4 " (½ " ) | 5 | " fine. |
| Overflow to buddles | 15 | " slimes. |
| Total | 60 | tons per 24 hours. |

## Shaking and Revolving Screens.

The revolving screen is more generally used than the flat shaking screen, although the latter offers some advantages in simplicity and cheapness. For the purposes of concentration, sizing in screens is generally conducted wet, and spraying jets of water are used inside or outside the revolving screens. The screens are sometimes cylindrical, with shafts inclined to the necessary angle, or they are built of conical form on a horizontal shaft. The coverings of screens vary in different countries, and according to the size and character of the material treated. The coarser screens are usually of punched steel or iron, occasionally of sheet copper; the finer sizes are of iron or brass wire cloth. The usual practice in concentration mills, where coarse crushing and jigs are necessary, is to employ screens only above 8 or 12 mesh, and below this to use hydraulic classifiers; but in some cases where intimate mixture of two minerals—say galena and zinc blende—necessitates close jig work and perfect separation, revolving screens as fine as 40 and even 60 mesh brass wire cloth have been successfully run, and excellent work accomplished on fast running jigs down to this size.

The wear of screens and delay incidental to changes of the covering on breakage, and the almost necessary employment of elevators to get the requisite fall in a mill, make it decidedly preferable to use hydraulic classifiers as far as possible in place of screens. The separation into equal sizes by a revolving screen, is more desirable for subsequent jig work than the classification into equal falling particles effected by a hydraulic separator, if the minerals to be separated do not vary much in specific gravity; and for this reason, the character of the material and closeness of jig work necessary, will regulate the extent to which one can replace the other system of preparation. Less water is necessary in jigs working the discharge of a hydraulic separator than if working from a revolving screen, owing to the greater uniformity in the sizes of the particles from the latter.

**PLATE 475. CODE WORD: ROGREGALE.**

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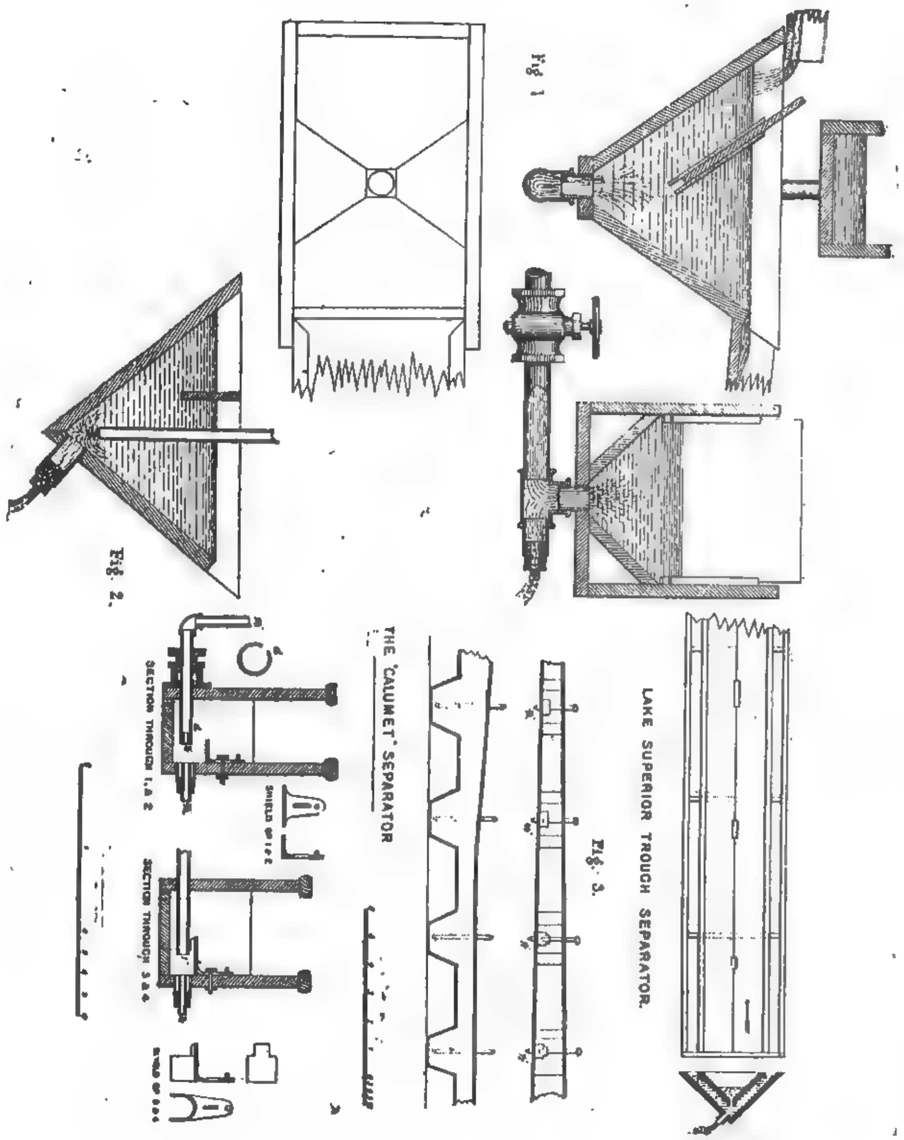




# METHODS OF CONCENTRATION.

The different methods of concentration can be classed roughly in two divisions for facility of description, viz:—

(*a*) Coarse crushing, and subdivision of treatment between two or more kinds of concentrators.

(*b*) Fine crushing, and direct treatment of the whole resulting pulp by one kind of concentrator.

As a general rule the ores of gold and silver come under class (*b*) of fine crushing; but as there are ores of copper, lead, zinc, antimony, and massive iron pyrites, in which the gold or silver contents are of equal or greater importance than the base metals, it is necessary to consider both classes of work.

## (*b*) Coarse Crushing.

The base metals—ores of lead, zinc, copper, antimony and iron usually carry the heavy mineral in the massive form of bunches, pockets, stringers and seams through the waste rock; and, almost necessarily, in pretty large percentage in order to justify working. Where the base minerals carry gold and silver in profitable quantity lower percentages are workable, and frequently resort must be had to finer crushing in consequence. The treatment of this class of ores will be either by rolls, screens, jigs, and slime tables, or after the American practice of coarse stamping; hydraulic sizing, jigs and slime tables. Both processes have been frequently described, and there is no necessity for going into detailed description here. The selection of the slime-dressing machinery depends largely on the quantity of gold and silver present, which generally varies in inverse proportion to the percentage of heavy mineral in the ore. For working large quantities daily of a low grade ore, valuable chiefly or wholly for the baser metals, the usual custom is to use revolving buddles, either single or double-decked. Where the percentage of mineral is less, and its value in precious metals higher, closer work is profitable on the slimes, and Frue vanners are employed in addition to the jigs. The advantages of the revolving buddles consist in low first cost, large capacity, and ability to stand large quantity of water, which is always present in the pulp after the various operations of screening and hydraulic separation. The disadvantages of the buddles as compared with the vanners are, that they make no sharp line of separation between heads and tails, but produce a middling product, which must be re-concentrated; the operation also involves greater loss of fine mineral; and, further, the material must be carefully sized by hydraulic separators to get the best results, which is not necessary with the vanner.

When the Frue vanner was first introduced, it was assumed that sizing of the material would be as beneficial as in other slime-dressing machines, like revolving buddles, Rittinger tables, and end-dump tables; and the first pamphlets published describing the use of the machine made mention of the fact. Actual practice, however, soon determined that in almost every case, taking a product of 40-mesh crushing, better results were obtained by simply evenly dividing the pulp over two machines, than by making a separation by sizes into two portions treated separately. Without

going into the theory of particles of matter of various sizes and specific gravities in a moving current of water, the following illustration will be the best explanation of an apparent anomaly. In any concentrator but a shaking belt, if a flat heavy object—say a dime—be thrown among the pulp that is being worked, it will appear immediately with the concentrates or headings; its comparatively great weight, and small surface edgeways exposed to the water current, insures its immediate recovery. If, on the other hand, the same coin is put on a Frue vanner while in operation, it will not pass over with the fine mineral steadily delivered past the water jets. The shaking motion, by cutting away the supporting adhesion of the belt surface, owing to the inertia of the coin, allows the light current of water on the edge of the coin, to wash it backwards with the sand. The same action applies to coarse particles of sand mixed with fine particles of mineral; the latter adhere strongly to the belt, and are unmoved by the water current; while the inertia of the larger particles prevents adhesion to the rapidly shaking surface below them. Specific gravity of course also comes into play, as between two equal sized particles; but the effect of mere mass is such that the Frue vanner with smooth belt is not adapted to saving coarse mineral; an excess of wash water at the head drives down the coarser mineral, while the finest cling to the belts and safely passes the water jets. The introduction of the improved riffled surface belts on the vanners enables a coarser grade of ore to be worked in larger quantity, and with greater inclination and increased supply of water. For the regular smooth belt machine, a screen of 40-mesh (1,600 holes to square inch) is the usual limit for good work; coarser than this the work done is not so effective, and plenty of simpler machines are just as good for the coarser particles when sized. No mineral is too fine for the smooth belt vanner; it is essentially a slime machine, adapted to the very finest slimes, either alone or in mixture with coarser sand, as represented by the pulp from stamps using a 40-mesh screen. Of course perfect saving with any automatic machine is out of the question, and in speaking of the saving effected the terms must be received as merely relative. The subject of closer saving than is possible by a single treatment will be touched upon later. In taking the ordinary work done in gold and silver mills, it must be remembered that the ore is simply stamped direct over a single machine and allowed to run to waste, and this simple process gives clean concentrates, and usually from 80 to 90 per cent. of the total heavy mineral—a percentage which can be increased, if the material justifies it, by a second treatment. In some cases the loss of silver and gold is greater proportionally than the percentage of the loss of the heavy mineral; the precious metals running more with the specially brittle minerals, or the more finely divided ones; and although theoretically, excellent concentration may be done according to percentage of mineral saved, the loss of gold or silver is really much larger than is indicated by the mineral recovered. In such cases it is of great importance to continue the operation, as a very slight increased saving of mineral may mean a largely increased recovery of the important metals.

The advantages to be derived by steam stamping and hydraulic sizing, as compared with the use of rolls and screens, have already been touched upon. Steam stamps make less slimes than gravitation stamps. A heavy blow is struck, but the crushed material is driven rapidly through the screens as quickly as reduced, and is not subjected to much unnecessary crushing. The great simplicity of the works, compact form, small amount of machinery subject to wear, economy in labor, and freedom from delays are self-evident advantages to put against the efficiency of rolls and screens as preparatory for the most perfect jig work. The John Collom jig, used almost universally on Lake Superior, and adopted largely of late in concentration mills for copper and lead ores, is an excellent machine, compact in form, and, by reason of its plunger motion (from a tappet and spring action), is capable of being adjusted



while running, and with greater facility than by the adjustable eccentrics used on the ordinary Hartz jigs. The success of the Anaconda Copper Company, in its adoption of the Lake Superior system, has led the Broken Hill Mining Company, of Australia, to employ the same machinery on silver lead ores; and other mines are coming round to the same process, as its advantages for economical working on a large scale become apparent.

When close work is necessary on the slimes of coarse crushing mills, on account of the value of fine mineral, it is necessary to settle off the excess of water in large pointed boxes before running the pulp to the Frue vanners, otherwise their capacity and closeness of work are much impaired. For this reason, and others to be mentioned, the improved riffled belt vanner is to be preferred for such mills as treat large quantities of slimes. The improved belt will stand twice the quantity of water and pulp that an ordinary vanner will; and where used in mills to take the direct product of gravitation stamps, one is placed to each five stamps instead of two of the ordinary belts required for close work; in fact, on certain ores, one of the improved belts has been used for ten stamps. The new belt is placed steeper, shakes somewhat faster, and requires more water than the old belt. The riffled surface retains and carries up a larger proportion of sulphurets than the plain belt at the same speed of travel, so that it has its advantages on ores containing much sulphurets. In Nevada, experimental crushing by five stamps through a 24-mesh screen, direct on to one of the improved belts gave very fair results. Often the finer jig work done in mills is not very good, as fine mineral is delivered with the coarser sand from the hydraulic separators, and is partially lost in the jig tailings. In such cases the improved belt vanner seems to offer chances of increasing the yield. Late tests at Tuscarora, Nevada, point to this larger application of the machine, as one belt is doing better work than two fine jigs on the material as sized for the latter, and is treating up to 17 tons per day, with a saving of 85 per cent.

The various new concentrators which come out yearly are usually modifications of existing machines, pans, upward water currents, or shaking tables. For coarse mineral nothing can be simpler, cheaper or more perfect than good jigs, where proper sizing is adopted. The usual idea of the gold miner is that a gold pan represents perfection of work in concentration, and various machines crop up again and again with claims of reproducing the action of a pan; the fallacy of this has been explained on page 8, and the failure of the machines themselves is the best illustration of the fallacy.

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### (*b*) Fine Crushing.

For the preparation of the ore requiring fine crushing, say below 20-mesh screen, stamps are almost universally used, except where of late the Huntington roller mill has come into use. The various pulverizers which are advertised in the markets, may have in some cases merits of their own, but cannot be cosidered in this paper, which deals simply with modifications in the application of well-known and existing machinery. The Huntington mill having been in steady use for several years in California, alongside stamp mills, has established its right to consideration in any article on fine crushing. In California it has been proved that this mill can be run continuously from year to year with very moderate wear and tear, so much so in fact on certain ores, that at the Spanish Mine, an ore yielding less than one dwt. of gold per ton has been worked to a profit, owing to peculiar facilities for cheap quarrying (rather than mining). The advantages of the mill consist in its low cost of freight to mines—being only one third the weight of equivalent stamping plant; its facility of erection; and the small power required to run it. As the mill uses screens

to regulate its discharge, it gives a product like stamps, ready for immediate treatment. The rapid rolling action of the crushing faces is effective as a preparation for concentration, and compares very favorably with stamps as to the product of slimes. As in stamps, amalgamation of free gold takes place inside the mill, and outside on copper-plates if these are used. For crushing soft and fine ore, the mill has decided advantages over stamps; and has therefore its sphere of usefulness as a re-grinder, and for working soft ores, in which application stamps are very unsatisfactory. An automatic feeder is used with the mill, so that no extra labor is involved as compared with stamps. On page 14 attention was called to the advantages of re-grinding the coarser tailings of some gold ores carrying fine gold. For this the Huntington mill can be made effective by proper regulation of speed, and has the advantage of also securing the amalgamation at the same time.

Of late, rolls have been advocated for fine crushing, and where the operation has to be performed dry as a preparation for roasting with leaching or chlorination, there is no question of the advantages to be gained. For ores requiring wet treatment, however—free gold and silver ores, and concentrating ores—there is nothing but disadvantage in rolls. Although there are various devices for both concentrating and amalgamating dry pulp, it is quite certain, from the failure of these processes in practice, though known for many years, that where water is obtainable, dry treatment is not worth considering. The mere item of drying the ore, and the disadvantage of dust in dry crushing—even if the processes be granted the full efficiency of equivalent wet methods—are sufficient to prevent any serious consideration of dry treatment, except as a matter of necessity from the absence of water. No one desires to dry an ore, crush dry, and then wet it again; and the fine crushing wet in rolls has obvious objections against it. For dry crushing, stamps are not nearly so effective as for wet work; and, therefore, what would be a favorable comparison for rolls in one case, becomes very different in the other. Rolls require screening and re-screening, with steady return of uncrushed particles; and all this means excess of water introduced, and the running of screens and elevators in addition to the crushing machinery. Again the surfaces of roller shells must be kept turned up true to do effective work fine crushing, or their capacity drops directly; while the capacity of stamps varies very little with wear of castings, as increased drop tends to neutralize decrease in weight. Some ores, containing clay, will be pressed into thin cakes by the rolls, and become an increasing factor in the returns from the screens.

From the above considerations it will not be necessary to include, for the class of ore under consideration, anything but stamps and Huntington mills; the former for hard rock, the latter for soft ores, and for re-grinding jig or stamp tailings. The Heberle mill is used, both in Germany and the United States, for re-grinding jig tailings. It consists of two vertical steel plates, with roughened faces, running rapidly, but at different speeds, in the same direction. Its adoption in the United States by the Anaconda Company shows that it has merits of its own, one of these being the reasonable proportion of slimes produced in its operation. The wearing plates are made of various kinds of special hard steel. As already pointed out on page 21, various new pulverizers may have their utility in grinding small quantities of material, and especially where the same is already reduced in size—e. g. jig or coarse stamp tailings—whereas the same machines are not worth considering at present on their claims of superseding stamps and rolls for the preliminary crushing of the crude ore.

Until quite lately steam stamps have been considered as only applicable to coarse crushing, with screens of not less than ⅛th inch holes; but work done on silver ores in Montana, and gold ores in the Black Hills, has opened a larger application of the machines to stamping as fine as 30-mesh. The advantage of the steam stamp in space, labor, and concentration of work, is evident; but its economy as to power is not established as compared with gravitation stamps for fine crushing. With the regular stamps more work is thrown on the rock breakers, but the power can be applied for the whole work in the form of a perfect steam engine as against the comparatively simple steam-cylinder of the heavy stamp. The work of a really good modern stamp mill, with a first-class compound condensing steam engine, leaves very little room for improvement as to economy of fuel; and the advantage of subdivision of the work among a number of batteries is that stoppages for repairs and and breakages only affect a small part of the crushing capacity at the time. Again, water power is applicable to the regular stamps in a simple and direct manner, insuring the fullest efficiency. For steam stamps it has been proposed by Mr. Stallman to use water power to compress air for use in place of steam; but this could not be done with a limited water power, as being a much less direct application of the force, compared with gravitation stamps driven from a water-wheel.



In Montana it is stated, on a fair comparison between both kinds of stamps, that the steam stamp makes less slimes in crushing than the gravitation stamps. This would be a direct advantage in concentration. Figures are not at hand to illustrate this or establish the matter of comparative cost, but enough has been stated to show that the steam stamp must be considered in future by those who contemplate erecting the largest and most economical concentration plants.

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A few words on some special propositions in fine ore concentration may prove suggestive in getting the highest results out of present methods and machinery.

There are certain ores of silver and gold which it is difficult at first to class in the proper system of treatment; and the presence of one or both of the precious metals, as well as the character and quantity of base metal sulphides present, will have an influence on the selection of the machinery.

To cover the well-known ores of both metals for which fine concentration is likely to be applicable, the following subdivisions can be assumed:

(1) Gold ores with less than 20 per cent. of sulphurets, little or no silver.
(2) Combined gold and silver ores, with less than 20 per cent. of sulphurets.
(3) Silver ores with less than 20 per cent. of sulphurets.

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## (1) Gold Ores.

As a rule, the ores of this class contain free gold in addition to that locked up in the sulphurets, and it is always best in such cases to use copper-plates in advance of concentration. Under the head of Gold Amalgamation these ores have already been described and their treatment suggested; for such as contain finely divided, brittle, or rich sulphides and tellurides, the remarks on close and double concentration, to be made on the silver ore class, will be equally applicable.

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## (2) Combined Gold and Silver Ores.

In this class come some of the most difficult ores on which to decide the treatment, because a process adapted to the extraction of gold may be very inefficient for recovery of the silver, and *vice versa*. When one of these metals is in small proportion as to value, it is frequently sacrificed to the most profitable process for the other metal. For example, many of the base silver ores of the United States contain from 5 to 15 dwts. of gold, and from 20 to 50 oz. of silver, per ton. On these ores dry stamping, roasting, and pan amalgamation, is mostly used; which will, under proper conditions, extract 90 per cent. of the silver, but only 40 to 60 per cent. of the gold.

The introduction of coarser crushing, instantaneous roasting by Stetefeldt furnaces, and double leaching by the Russell process, has of late come into prominence on this kind of ore, and is giving excellent results on some varieties, both as to economy, and the extraction of both metals.

For either of the above processes, the ore must of necessity be of a fairly high grade, and without too high a percentage of gold in the total value. When ores contain but little base metal, with high proportion of gold value, the roasting process is avoided if possible, and either copper plates and concentration, or concentration and pan amalgamation, are used. On this latter combination process very little has been published, and its importance will justify our giving a few details.

Pan amalgamation is effective chiefly on native gold, native silver, chloride of silver, and simple sulphide of silver. When the silver is in combination with sulphides, antimonides, arsenides, and tellurides of the baser metals, the pan process becomes ineffective and expensive. By contact with iron surfaces, heat, and the addition of some chemicals—chiefly salt and sulphate of copper—a partial decomposition of the complex minerals is effected, and some of the silver amalgamated; but the wear of iron, loss of quicksilver, cost of power and chemicals, and the production of base bullion, together go far to neutralize the gain made in recovery of the silver. In such cases a great benefit is derived from combining concentration with amalgamation, for the two processes are applicable to different minerals. The light flocculent chlorides and sulphides of silver can be amalgamated to a high percentage, while concentration is almost useless on them in the form in which they exist in a free or decomposed ore. On the other hand, concentration can be made very effective on the undecomposed complex minerals, for which amalgamation is ill adapted.

There are two methods of combining the processes, according to their order, i. e. whether the pans are used first or the concentrators. In either case, the Boss continuous process of pan amalgamation is much more convenient and economical than the old settling tank and intermittent charge system. The former process, as is well known, consists in placing pans and settlers in a row on one level, connecting them by short pipes, feeding the pulp continuously into the first pan of the series, and allowing it to discharge continuously from the last settler. Its advantages consist in economy of space and labor, and dispensing with the trouble of settling tanks; and, in connection with concentration after amalgamation, its great superiority lies in its continuous operation, as insuring a regular feed to the concentrators, which is all-important, and almost impossible to obtain from the intermittent settler discharge of the old tank process. When concentrators are used before the pans, the tank system can be used, as well as if the stamps discharge direct to the tanks; but the continuous amalgamation of the tailings of the concentrators, if the Boss system be used, would simplify the adoption of the pointed box system of automatic settling, advocated on page 31.

In regard to the relative advantages of the two orders of succession, it may be briefly stated that concentration before amalgamation is the natural method, because it relieves the pans of the base minerals, which are a disadvantage in amalgamation, and the subsequent concentration of which is made more difficult by the grinding or attrition of the minerals in the pans. The only argument against the universal adoption of this order rests on the disadvantage of sometimes having native metals (and some chlorides and sulphides) enter the concentrations, instead of appearing as bullion, which they would otherwise do; and also that very perfect settling of the slimes from the concentration tailings is necessary to prevent loss of flaky silver chlorides and sulphides. Where the free metal is gold, the first-named disadvantage can be overcome by using copper plates before the concentrators, and this process was adopted by the Montana Company with great success, after first trying pans before the concentrators. The change in the order of working by the Montana Company has been productive of a considerable gross increase in percentage extracted from the ore, a reduction of one-half in the loss of quicksilver, and a saving in the wear of pan casings, fuel, and chemicals; as well as the production of a higher grade of bullion. In this Company's 50 stamp mill, the tailings of the concentrators run into the usual settling tanks, the Boss process not being employed.



Comparing the combined process with dry crushing and roasting, the advantages of the former consist in a reduction of the cost of working, fully one-half that of dry crushing; a crushing capacity of double for the same number of stamps; a decreased cost of erection; and a higher saving of gold present in the ore. Against these advantages may be placed simply the increased percentage of silver extracted by the dry process when the ore is base. A curious instance of successful roasting of a gold and silver ore which is very free from base metals, exists in Idaho, at the Dickens Custer Mill. The ore treated is that of the Lucky Boy mine; it consists of a mixture of quartz and calc-spar, carrying free gold, native silver, brittle silver ore, and occasional minute crystals of iron and copper pyrites. The total quantity of base mineral present is so small, that dark blue seams and discolorations merely break the general pure whiteness of the ore. This ore is crushed dry and roasted with 3 to 4 per cent. of salt in Bruckner furnaces at a low heat; with a resulting chloridization of 50 per cent. of the silver, and a total extraction in the pans up to 90 per cent. of the silver and 80 to 85 per cent. of the gold. An average proportion of the two metals present in the best ore treated is 1¼ oz. gold and 12 oz. silver per ton of 2000 lbs. It is probable that the unusual freedom from base mineral in this case accounts for the high extraction of gold after roasting. Although apparently so successful, it is questionable whether better commercial results would not follow from a change to wet crushing on this ore; because the cost of treatment is high, also a selection of the ore is necessary at the mine, and this increases the cost of mining, and involves loss of lower grade ore not workable by itself.

When combined gold and silver ores carry over 10 per cent. of base minerals, it usually happens that the silver does not exist equally through the minerals present, but is concentrated in one of them as a rich brittle ore. It follows from this that concentration is often very ineffective on such ores; because, while 90 per cent. of the heavy base minerals may be saved in the concentrates, the loss of the fine silver-bearing mineral in the slimes may be fully 50 per cent. of the assay value of the crude ore. In some cases of a base ore, the clean concentrated heavy minerals do not assay more than the original ore from which they were separated.

From the above remarks it will be seen how important it is to determine, by actual tests on any given ore, the choice of dry or wet crushing, the adoption of concentration or otherwise, and the relative order of amalgamation and concentration when the combined process is decided upon.

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### (3) Silver Ores.

The remarks already made as to ores of Class (2) apply equally in many cases where silver alone is present; so that it is unnecessary to repeat anything as to dry crushing, pan amalgamation, or the combined process of concentration and amalgamation; and the only points now to be described are those connected with special difficulties in concentration of silver-bearing minerals, equally applicable to gold in the case of tellurides and rich sulphides.

Concentration is never absolutely perfect; for, putting aside the loss of mineral particles attached to rock particles, it is always possible to show by hand-panning a loss of mineral in the tailings of a concentrator. The quantity of mineral so discovered

determines the relative efficiency of the concentrator employed. Up to the present, no machine has given better results on finely crushed ores carrying up to 20 per cent. base mineral, than the Frue vanner, and for this reason our remarks are confined to this machine for the special cases to be considered.

In working an ordinary gold ore containing under 10 per cent. of mineral, the proportion of fine mineral in the tailings will not exceed one-tenth of that present, if the concentrator is properly adjusted, not over-crowded, and has regular feed and speed. On the large majority of gold ores a loss of one-tenth of the mineral present—after the free gold has been extracted by copper plates—represents so small a value that any closer concentration is not necessary. As an illustration, an ordinary ore may contain 10 dwts. of gold per ton, of which 6 dwts. are free gold, and 4 dwts. combined with sulphurets—i. e. combination in its broad sense, as described on page 19. A loss of one-tenth of the sulphurets carrying 4 dwts., would make the tailings assay from this cause alone $\frac{4}{10}$ dwt. per ton, a value which would usually be ignored. It does not follow that this loss of mineral is entirely necessary, for a second concentration would reduce it, as will be shown.



# DOUBLE CONCENTRATION.

There are ores, of both gold and silver, in which the sulphurets are so rich that even a very small loss by weight, involves a large loss in assay of the precious metals. Such minerals as tellurides of gold and silver, ruby and brittle silver ore, come under this head. In concentrating the tellurium ores of Colorado, some of the very finest slime mineral overflowing from the concentration tanks of the Frue vanners assayed as high as $25,000 per ton in gold and silver. It is obvious that when very rich mineral exists in the ore, extra care and expense in close concentration are necessary.

When panning tests on the concentrator tailings show a distinct head of fine mineral, closer concentration can still be done, if this fine mineral be rich enough to pay for it. It will be found that such fine mineral is really no finer nor more difficult to save than much of that already caught in the concentration tank; its loss is not wholly necessary. It has escaped contact with the belt surface, in the same way as fine gold will escape in part from the short copper table, but be saved in running over a longer one, having more chances of contact in the greater distance. In some cases attempts at concentration of this mineral from the tailings of the first concentrator have failed, for the reason that one vanner placed below another does not have a good chance, owing to excess of water introduced by the clear water distributor of the first machine. This difficulty can be overcome in several ways, and a consideration of the following suggestions may lead to a more perfect result on many ores now subject to considerable loss in the concentration.

The first and natural course to overcome the crowding of the second vanner is to split the tailings of the upper machine and feed on to two vanners below, and this course will certainly give good results. Another method is to get rid of the excess of water by use of the large settling box previously described; using one box to two, or three, or even four machines, and splitting the thickened discharge on to three or four machines below. Still another course is to size the tailings of the first machine, putting the coarse portion on one vanner and the fine on another below; or even running the fine alone on one vanner and throwing to waste the coarse if the mineral be found mostly in the overflow of the hydraulic sizer. In this latter case the excess of water introduced by the hydraulic sizer may have to be removed by using the large settling box, to thicken the pulp before feeding to the tailings machine. This sizing of the tailings is not, as might appear at first glance, in contradiction to previous remarks on the preparation of pulp for the vanner; because the larger particles of mineral have already been extracted, and its utility rests in this case more on the lessening of the work for the second vanner than on the effects of the sizing itself as a preparation. In this double concentration of valuable ores is to be found the true solution of close concentration, when proper precautions are taken to give the lower concentrators a fair chance on the small quantity of fine mineral escaping the first machines.

### Improved Belt Vanner.

In this connection the recent introduction of a new form of belt surface on the Frue vanner for special work is likely to be of considerable service. The improved belt consists of a broken surface, made up of a number of short rising planes, and re-

quires a modification in the supporting shaking frame, and also in the water distributor. The other points of difference have already been described on page 39, as well as the application of the belt to a coarser class of work.

In the double concentration of valuable ores, or the treatment of base ores carrying rich silver-bearing minerals which escape in the concentration of the mass of sulphurets, the larger capacity of the new belts would lessen the number of vanners otherwise needed. For instance, the pulp of five stamps delivered to one improved belt machine would be freed of a large percentage of the sulphurets at once; and the tailings of this machine split on to two or even three of the plain belt machines would yield nearly the whole of the fine rich mineral which it is possible to separate by concentration. The use of hydraulic separators and large settling boxes, as already suggested, would, in case of coarser crushing than 40-mesh, assist the final operation, and make at once a simple and most perfect mill for any ore which needs finer grinding than rolls are adapted to give. A five-stamp battery, with screen of 14 to 30-mesh, will, with a low discharge, prevent much of the sliming of mineral so injurious to close concentration. Take, for illustration, a battery using a screen of 20-mesh; the improved belt will save all the coarser mineral from the pulp, and the loss will be in fine mineral. This fine mineral can be run off with the overflow of a small shallow hydraulic sizer, discharging at the bottom the coarse rock particles between 20 and 40-mesh, which would not work well on the plain belt vanners below. If the overflow of the separator carries too much water—as probable for two plain belt machines—it is made to pass through the large settling box, of which the thickened pulp discharge is divided on to the two belts below. The overflow of the large settling box will not contain any mineral likely to be saved by a concentrator. In certain special cases, where some of the fine mineral escaping the the upper improved belt is still heavy enough to settle with the coarse sand in the hydraulic separator, this discharge can be run on a second improved belt below, and the overflow go through the large settling tank, as before explained, to one or two of the plain belt machines. For if the mineral will settle against the upward current of the hydraulic sizer, it will separate readily on the improved belt, although it has accidentally escaped the first one. In each case it is necessary to experiment with the particular ore, to determine the best size of screen (using always the coarsest possible), and also to decide the best method of using the hydraulic sizer, so as either to drive the whole of the mineral into the overflow, or to allow part to settle with the coarse sand discharge, according as this last is run to waste or worked over again.

In advising the use of the large settling box it is intended that the siphon discharge, as fully described shall be used. Millmen may be frightened at the height of this box, and the consequent large fall in mill site apparently necessary; but the actual loss of fall is not over 8 feet at most, by use of the siphon discharge, and its other advantages have already been explained.

At the Silver King Mine, in Arizona, a complex silver ore was concentrated for several successive years by stamping over a single row of vanners, and very close work was done, with production of concentrates containing 800 to 1200 oz. of silver per ton. The ore contained native silver, sulphide of silver, ruby silver, brittle silver, argentiferous grey copper, galena and zinc blende, with some pyrites. To further increase the percentage saved, a row of six vanners with belts 6 feet wide, was placed below the twelve upper machines with the regular 4-foot belts. These lower machines did good work on the tailings of the first, though the concentrates were of lower grade and consisted largely of zinc blende. The tailings from the upper concentrators assayed 4.11 oz. silver per ton. The lower machines treated 12½ tons each daily, and careful assays, made in working 10,178 tons of ore, showed that the final tailings assayed only 2.03 oz. or 7½ per cent. of the original value of the ore worked. These results show clearly that tailings in some cases may be reduced 50 per cent. in value by a proper double concentration; and in this particular case, an actual saving of 21,509 ounces of silver was made from the tailings of 10,178 tons of ore, with a merely nominal increase in the daily expenses of the mill for 4½ months' work.



The good work done by the vanner has rather blinded millmen to attempting any improvement by double concentration. It is generally assumed that if two machines are placed to five stamps, the last thing has been done in precautions to insure close work; and it is believed either that the mineral then escaping is too fine for concentration, or that some new invention must be awaited in concentrators. This is in effect the somewhat absurd conclusion, that because the machine does remarkably close work on fine mineral, it must not be used twice over. In gold milling, if fine gold escapes an 8-foot plate, an additional length is often used with success; and it is not assumed, because 8 feet is long enough on most ores, that the utility of copper plates ends with this length. In some cases of valuable ores, millmen have used an extra vanner to each five stamps, making three; and, by this, have increased the saving in a marked degree. The great test of the possibility of still further improvement is by hand-panning on the tailings. If a distinct head of mineral is easily shown, closer work can be done. The subject of hand tests has been treated on page 8. It will be found that the white enameled placque, or the "batea," is greatly preferable to the gold pan for such tests, and the "batea" can be used by anyone with very little practice. An examination of the excessively fine concentrates saved in regular working by a Frue vanner, will convince anyone that the fine mineral shown in hand-panning the tailings is not a necessary loss in concentration, but an accidental loss, which can be reduced—if profitable so to do—by a second treatment. This is an immediately available remedy; and commends itself to common sense as compared with waiting for the invention of an absolutely perfect concentrator—of which inventors may dream, but practical men will not expect to see.

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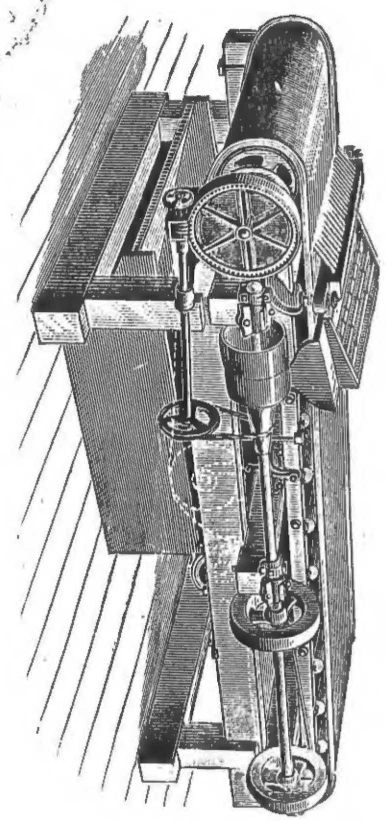

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